AUTOMATIC TELEPHONE SYSTEMS

BY

WILLIAM AITKEN, M.I.E.E., A.Am.I.E.E.

AUTHOR OF "AITKEN'S MANUAL OF THE TELEPHONE."

VOLUME ONE

CIRCUITS AND APPARATUS AS USED IN THE PUBLIC SERVICES

LONDON

BENN BROTHERS LIMITED

"THE ELECTRICIAN" OFFICES, 8, BOUVERIE STREET, E.C. 4

1921

DIRECTOR OF INDUSTRIES ... LIBRARY ... BENGAL

PREFACE

The subject of Automatic Telephony requires very special treatment, owing to the infinite mass of detail from which it is built, and the complicated circuits diagrams necessary to illustrate it.

In the past the diagrams have either been fragmentary or so reduced in size as to be unintelligible when made suitable for a book of ordinary size. Even when folder sheets have been used, no, or only slight, attempt has been made to simplify the diagrams, these, in most cases, being reproductions of the manufacturers' diagrams. The latter are good for the expert, or one familiar with the system, but are rarely suitable for the student or learner.

This book has for its objects the making of this most complex subject intelligible to any one having some electrical knowledge, and that, not by writing down to the learner, or giving scrap diagrams for each feature, but by rearranging the diagrams eliminating unnecessary crossing lines, simplifying the form and by dividing them into sections when necessary, or continuing them section by section, in such a way as to show the relationship and interconnection of the system as a whole.

This result is greatly facilitated by a new method of describing the diagrams, which consists in numbering a circuit from end to end with the same symbol, so that each circuit can be readily traced. This method was designed by the Author some years ago, and has been used in Patent Specifications, but to the best of his knowledge has not been used in book form. This arrangement has been called *bus routing*, as it resembles the bus route numbers used in maps of London to show the route taken by a 'bus from terminus to terminus. This device also allows of a simpler and briefer description. The circuits are taken in the order of operation and numbered progressively, so that the expert can read the diagram with only occasional reference to the text. The student will follow the text more carefully, find the reason for the peculiarities of the circuit, and the reasons for the particular devices or parts, and their functions.

This method of designating circuits makes unnecessary the scrap, or one feature, diagram. These are sometimes misleading as they eliminate the associated circuits and show the feature out of perspective, and thereby out of proportion, being analogous to quoting or extracting a paragraph or sentence from written matter, and losing the meaning it had when read with the context.

The increased size of the page allows of the diagrams being drawn to a comparatively large scale, so that they can be read with ease. Folder sheets have been eliminated as far as possible. For long diagrams, showing a system from end to end, where possible the diagram has been divided into sections. The breaks in the continuation lines have their ends marked with the circuit number, so that the gap can be bridged readily.

PREFACE

Folders are used when the circuit diagram is unsuitable for division, and such sheets only fold in one direction.

The relays are drawn with the contacts away from the winding in many cases, but the contacts are always kept in line with the core or centre of the winding. This prevents the confusing crossing of lines that frequently causes a diagram to look more complicated than it really is. The short double line, or single thick line, is always the moving spring that travels towards the coil when the coil is energised. The moving spring then breaks from a back contact, and makes with a front one, and the like. Relays slow to de-energise by having a massive ring of copper on the core are shown with the lower part of the core shaded.

Relays and magnets are designated by the circuit symbol, which is prefixed by the letter R or M respectively. The manufacturers' designations are also given in the more important diagrams.

The field covered is practically the whole subject of Automatic Telephony, and this is only made practicable by the use of condensed methods. The important circuits and arrangements of the principal standard or commercial systems are illustrated and described. Obviously the detail which is common to all is not shown, but representative examples are taken from each, and some dealt with in detail on one system and other features in more detail on other systems.

Particulars are also given of systems which are not so well known, but which give such promise that it is reasonable to believe in the future they may find a place in public use. These will be interesting also to the student or inventor who desires to enter into the spirit of automatic design.

Arrangements and devices of well-known manufacturers and inventors, which have been designed to fill a known requirement but have not yet been introduced into public service, are also shown.

Indeed, the book in addition to describing the well-known systems clearly and succinctly also aims at indicating the possible trend of future developments.

It is felt by the Author that the subject of Automatic Telephony is in a more unstable condition to-day than at any period of its existence. It is in a state of flux, and the question of "standardisation" must be postponed for several years, at least. The Western Electric Co., with its "Panel" system composed of 500-line switches, challenge the world that that is the only efficient traffic-carrying medium for the great cities of the world. Other designers must meet that challenge, and we have the battle of large and expensive switches *versus* small switches, with or without special wiring schemes.

Telephony has already passed through two great phases and is entering the second section of a third, viz., magneto and local battery working; common battery with lamp signalling; and Automatic or machine switching, the two former being manual systems and the latter eliminating the human factor except for special services. The first section of the third phase is the use of 100- and 200-line switches, the former being a decimal system and the latter a non-decimal system. The second section is the access to very large groups, *e.g.*, 1,000 lines.

Owing to the incessant change, the continuous advent of new development, it has been felt necessary that a new book on this subject, that aims at being kept up-to-date, must have special facilities for eliminating obsolete matter, for putting obsolescent features in their proper relationship to the whole, and for readily adding new developments as they appear. Instead of the usual *Chapters* the book is divided into short *Sections*. A section

is merely a division which may contain one or several pages, and may describe one feature or a system. It will contain such matter that may readily be replaced by new, if it should become of little value or be abandoned.

The Author desires to express his indebtedness and thanks to all those who have assisted him by furnishing interesting matter, particularly to Sir William Slingo, late Engineer in Chief, G.P.O.; Sir William Noble, Member of Council, Institution of Electrical Engineers, Engineer-in-Chief, G.P.O.; the Officials of Western Electric Co., Automatic Electric Co., Automatic Telephone Manufacturing Co., Siemens Brothers & Co., Relay Automatic Telephone Co., Coventry Automatic Telephones, Ltd., and many friends who have given valuable assistance.

DIRECTOR OF INDUSTRIES LIBRARY 13-JUL.1925 BENGAL

OUTLINE OF CONTENTS OF VOL. II. (IN THE PRESS)

EQUIPMENT IN SUBSCRIBERS' OFFICES. Simple extension lines With plurality of instruments -With switches With coin boxes With call meter.

PARTY-LINE WORKING. -Two-party circuit -Four-party circuit - Multi-party circuit Frequency selecting connector Frequency selector Reverting calls Discriminating by selector Look-out circuit Methods of signalling.

SMALL SWITCHBOARDS FOR SUBSCRIBERS' OFFICES. Small cord boards Twenty-five to sixty-line boards Cordless boards.

EQUIPMENT FOR SMALL OFFICES. Branch and other small offices District offices on manual systems Community offices Branch offices in multi office system Branch offices with direct and party lines.

BRANCH OR SATELLITE OFFICES IN RELATION TO MAIN OFFICE. Supervision of a branch office at the main office - -Local connections without utilising trunks to main office.

SEMI-AUTOMATIC SYSTEMS. A. T. M. Co. manual to automatic working Siemens' manual to automatic working - W. E. Co. semi-automatic system Siemens traffic distributing system Clement auto-manual system Automatic to manual office junctions Closed branch office on a manual system Mixed services in automatic and semi automatic systems Thomson's call indicator A. T. M. Co. call indicator.

SPECIAL IMPULSING DEVICES. Betulander relay impulse converter A. T. M. Co. equalising duration of impulses Methods of repeating impulses.

INTERESTING AUTOMATIC SWITCH DESIGN. Intersecting bar switch Three-movement 500-line switch Two hundred line Strowger connector Two digit vertical and rotary selector Keith 1,000-line connector Strowger multi-wiper connector (increases size of system without additional dial movement) Vertical rise and horizontal projection switch - Hultman's large group and line-hunting switch.

METERING OR REGISTERING OF CALLS. By increase of current Telephone unit - Laidlaw, Grinstead and Pettigrew's method A. T. M. Co. (A. E. Co.) method.

TRUNK OR TOLL-LINE WORKING. A. T. M. Co. circuit Superimposed or phantom working Telegraph on telephone trunks.

WIRING OF SWITCHES AND THE LIKE. Wiring expedients to increase the efficiency of trunking Overflow switching Distribution of circuits between primary and secondary Keith line switches Wiring of Switches (Siemens) Cabling of Switches (Keith) Grouping of junctions,

LAY-OUT OF PLANT.

TRAFFIC PROBLEMS AND CURVES TRAFFIC RECORDER.

POWER PLANT.

BY-PATH SYSTEMS ORDER-WIRE WORKING. RAILWAY TRAFFIC CONTROL.

PRIVATE AUTOMATIC INSTALLATIONS. Siemens' system Relay systems Stevens Couch autophone system, and others.

LIST OF SECTIONS

SECT.		PAGE
1	Introduction. The State of the Art	1
2	Some Definitions	3
3	First Principles	6
4	Dial Impulse Senders	11
5	Dial Adjustments	13
6	Dial. Special Features	16
7	Dial with Interchangeable Crown Wheel	17
8	Telephone Instruments	19
	STROWGER SYSTEM: AUTOMATIC ELECTRIC CO., CHICAGO, AUTOMATIC TELEPHONE MANUFACTURING CO.	
9	Switching Apparatus	27
10	Circuits of Selectors and Connectors with Side Switches	30
11	Keith Line Switch	33
12	Master Switch	35
13	Latest Form of Connector	36
14	Rotary Line Switch	39
15	Rotary Line Switch and Side-switchless Selector Circuit	42
16	Side-switchless Connector Circuit	44
17	Rotary Connector Circuit	47
18	Primary and Secondary Line Switch, First Selector and Connector. Circuit as used by British Post Office	50
19	Circuit of Single Line Switch and Rotary Connector	53
20	Impulse Repeater between two Automatic Offices, and between an Automatic and a Manual Office	56
21	Trunk Offering Circuit	59
22	Test Clerk's Connector Circuit and Dial Speed Testing	62
23	Testing Equipment and Circuits	65
24	Connector Testing	68
25	Selector Testing	72
	SIEMENS BROTHERS & CO.'S SYSTEM.	
26	Rotary Switch and Selectors	75
27	Circuits for a Four-figure Calling System	78
28	Discriminators for Private Branch Exchange (P.B.X.) Working	83
29	Fault and Group Alarm Signalling on Preselectors	87
30	Fault and Group Alarm Signalling on Selectors	90
	SIEMENS BROTHERS & CO.'S SYSTEM—*continued*	
31	Fault and Group Alarm Signalling on Connectors	92
32	Fault and Group Alarm Signalling on Motor Interrupters	94
33	Fault and Group Alarm Signalling on P.B.X. Connectors	97
34	Trunk Offering Apparatus and Circuits	99
35	P.B.X. Trunk Offering Connector	102
36	Testing Connector	104
37	P.B.X. Testing Connector	106
	WESTERN ELECTRIC CO.'S SYSTEMS. *Rotary System*	
38	Introduction. Power Drive	113
39	Apparatus. Call Finders and Selectors	116
40	Sequence Switch and Register	121
41	Assembly and Cabling	123
42	Fundamental Operating Features of System. Translation	125
43	Revertive Impulse Control	127
44	Explanatory Circuits. Line Finder connects with a Calling Line	129
45	Calling Line connects to an Idle Register	131
46	The Subscriber dials the Number of the Desired Line	133
47	The Brush Spindle of a Group Switch controlled by the Register	135
48	The Register controls the Building up of the Desired Connection	137
49	The Brush Carriage revolves and hunts for an Idle Trunk	142
50	The Brush Chooser and Brush Carriage of a Final Switch selectively controlled by the Register	144
51	Wanted Line Tested, Rung and Connected, or, if busy, Tone given to Caller	144
52	Connector cleared after Conversation	146
53	Connection registered after Conversation	148
54	The Register receiving Impulses and controlling the Selecting Operations	150
55	A 1,000 line Rotary Machine-switching System	153
56	Symbols used in Rotary System Diagrams	161

SECT. PAGE

WESTERN ELECTRIC CO.'S SYSTEMS—*continued.*

57 A 100,000-line Rotary Machine-switching System 164
58 Carriage Call (Called Number set up on Lamps) 180
59 Auxiliary Circuits in a Rotary System (Dead Level and Line) . . 186
60 Panel Automatic Apparatus . . . 189
61 Operation of Line connecting Switches . 189
62 Controlling Switches . . . 197
63 Transmission . . . 199
64 Advantages claimed for the Panel System 201
65 Panel System proposed for London . 204
66 Apparatus and Circuits . . . 207
67 500 line Panel Switch . . . 207
68 Bank and Wiper Construction . . 213
69 Horizontal-type Sequence Switch . 215
70 Calling Line Finders 218
71 Message Registering and Metering . 223

72 Changing over from a Manual to an Automatic System 228
73 Lorimer Automatic System . . . 233

SECT. PAGE

74 The American Automatic Telephone Co.'s System 244

RELAY AUTOMATIC TELEPHONE CO.'S SYSTEM.

75 Fundamentals of System and Apparatus 249
76 Circuit Operation of a Three-digit System 256
77 Impulse and Speech Repeater . . 260
78 Operation of a Subscribers' Sub-group . 261
79 Operation of a Three-digit Final Group . 263

SYSTEM OF COVENTRY AUTOMATIC TELEPHONES, LTD.

80 Apparatus 267
81 Operation of the Auto manual System . 273
82 Circuits relating to an Automatic System 274

83 British Engineering Standard Association's Terms and Definitions in Automatic Telephony 280

LIST OF ILLUSTRATIONS

FIG.		PAGE
1	Ten-line Automatic Switch, Explanatory Circuit	5
2	Hundred line Switch, Explanatory	5
3	Thousand-line Switch, Explanatory	5
4	Five-line Switch, Explanatory Wiring	7
5	Hundred-thousand-line System (Strowger)	9
6	A. T. M. Co. Dial (Front View)	11
7	,, ,, (Interior)	11
8	Siemens Dial (Front)	11
9	,, ,, (Interior)	11
10	W. E. Co. Dial (Three Views)	12
11	A. T. M. Co. Dial, Working Parts (Plan)	13
12	,, ,, Working Parts (section)	13
13	,, ,, Impulse Springs	14
14	,, ,, Testing Circuit	14
15	Dial with Interchangeable Crown Wheel	18
16	Dial Plate with Figures and Letters	18
17	Typical Wall Instrument	19
18	Typical Table Instrument	19
19	A. T. M. Co. Wall Instrument Circuit	19
20	,, Table Instrument Circuit	20
21	Siemens Wall Instrument Circuit	20
22	,, Table Instrument Circuit	21
23	W. E. Co. Wall Instrument Circuit	22
24	,, Table Instrument Circuit	22
25	Breast Transmitter and Head Receiver on Direct Line	23
	STROWGER.	
26	Connector, Early Pattern	27
27	Connector with List of Working Parts	28
28	Details of Bank Contacts	29
29	Numbering of Bank Terminals	30
30	Four-figure Circuit with Side Switches	31
31	Keith Line Switch, Early Form	33
32	,, ,, Present Form	34
33	Hundred-line Keith Unit	34
34	Keith Master Switch, Construction	36
	A. T. M. Co.:	
35	Connector, Latest (Four Views) A, B. / C, D.	37 / 38
36	Rotary Switch (Four Views)	39
37	Hundred-line Private Exchange, showing Rotary Line Switches	40
38	Line and Cut off Relay, for above	41
39	Rotary Line Switch Circuit	43
40	Side-switchless Selector Circuit	43
	A. T. M. Co. *continued.*	
41	Side switchless Connector Circuit	50
42	Rotary Connector Circuit	50
43	Primary Line Switch, as used by British Post Office Circuit	52
44	Secondary Line Switch Circuit	52
45	Selector Circuit, as used by Post Office	52
46	Connector Circuit, as used by Post Office	52
47	Single Line Switch, as used by Post Office	54
48	Rotary Connector Circuit, as used by Post Office	54
49	Impulse Repeater, for use between two Automatic Offices	57
50	Impulse Repeater, for use between an Automatic and a Manual Office	57
51	Trunk Offering Circuit	60
52	Test Clerk's Connector Circuit	62
53	Dial Speed Testing Circuit	63
54	Test Desk Circuits	64
55	Test Desk Distributor	64
56	Test Desk Connector	64
57	Test Desk Connector, for use without Distributor	64
58	Test Desk Keyboard Connections	67
59	Test Circuits for Test Desk Keyboard	67
60	Testing Circuit for small Automatic Offices	66
61	Faultsmen's Incoming Lines Circuit	68
62	Post Office Tester, No. 11A	69
63	Circuits on Connector for above	69
64	Tester No. 14 for Selector Testing	73
	SIEMENS:	
65	Rotary Line Switch	75
66	Rotary Line Switch (Another View)	75
67	Connector	76
68	Connector with Banks	76
69	Switch Relay Unit	77
70	Line Switch Fault Alarm Circuits	87
71	Second Preselector Fault Alarm Circuits	87
72	Line Switch Circuit with Alarm Signals	92
73	Preselector Circuit	92
74	First Selector Circuit	92
75	Second Selector Circuit	92
76	Connector Circuit	92
77	Alarm Fuse	91

FIG.		PAGE
	SIEMENS—*continued.*	
78	Motor Interrupter Fault Alarm Signal Circuit	95
79	Discriminator for P.B.X. Working Circuit	98
80	Trunk-offering Distributor (Two digit Selector) Circuit	99
81	Trunk-offering Connector Circuit	100
82	P.B.X. Trunk-offering Connector Circuit	102
83	Testing Connector Circuit	104
84	P.B.X. Testing Connector Circuit	107
	W. E. CO. ROTARY SYSTEM:	
85	Exchange (General View)	114
86	Power Drive	115
87	Line Finder	116
88	Selector with Sequence Switch	117
89	Terminal Bank of a Selector	117
90	Vertical Strips of Terminals with Ribbon Cable	118
91	Selector Brush Carriage and Brush	119
92	Selector Brush Chooser	120
93	Sequence Switch	121
94	Register	122
95	Register Relay	123
96	Front and Rear Views of a Bay of Selectors	124
97	Numerical Wiring of Selector Banks	125
98	Wiring from the Group Selectors	126
	EXPLANATORY DIAGRAMS:	
99	Revertive Impulse Control	128
100	Line Finder connecting with a Calling Line, Circuit	130
101	Calling Line connecting with an Idle Register, Circuit	132
102	A Subscriber dialling the Number of the Desired Line, Circuit	134
103	Brush Spindle of Group Switch controlled by the Register, Circuit	136
104	A Register controlling the Building-up of a Desired Connection, Circuit	138
105	Brush revolving to find an Idle Junction Circuit	141
106	A Brush Chooser and Brush Carriage of the Final Switch selectively controlled by the Register, Circuit	143
107	Wanted Line Tested, Rung and Connected, or, if busy, Busy Tone given to the Caller, Circuit	145
108	Connection cleared after Conversation	147
109	Connection registered after Conversation	149
110	The Register receiving Impulses and controlling the Selection Operations, Circuit	152
111	Selector Circuit	152
	W. E. CO. ROTARY SYSTEM:	
112	First Line Finder Circuit	162
113	Second Line Finder and first Group Selector Circuit, 1,000-line System	162
	W. E. CO. ROTARY SYSTEM—*continued.*	
114	Final Switch Circuit, 1,000-line System	162
115	Register Circuit	162
116	Adjacent "Cords" Circuit	162
117	Apparatus Symbols in Rotary System Diagrams	161
118	Subscriber's Line Circuit in a 100,000-line System	180
119	First Calling Line Finder in a 100,000-line System	180
120	Connecting Circuit in a 100,000 line System, including Second Line Finder First Group Selector, and Register-finding Sequence Switch	180
121	Second Group Selector in a 100,000-line System	180
122	Third Group Selector in a 100,000-line System	180
123	Final Selector (Connector) in a 100,000-line System	180
124	Register Circuit in a 100,000-line System	
125	Second Group Selector for Two-wire Trunks	178
126	Carriage-call Circuit (Called Number set up on Lamps)	186
127	Dead-levels Circuit to Work with Fig. 121	186
128	Dead-levels Circuit for Selectors in same Office	187
129	Dead-line Circuit	188
	W. E. CO. PANEL SYSTEM:	
130	Typical Panel Selector Frame	190
131	A Bank of Terminals	191
132	Soldering Tab Strip for above	191
133	Detail of Panel Frame and Selectors	192
134	Clutch Magnets in Frame	193
135	Front and Rear of Commutator	194
136	Details of Brush and Trip Device	195
137	Sequence Switch, Horizontal Type	198
138	General View of a Panel System Installation	200
139	Dial with Letters and Figures	202
140	B-position Keyboard for Manual Working	204
141	B position Keyboard for Carriage Calls	205
142	Switches involved in a Connection	206
143	Side View of a Panel Switch and Section of Bank	210
144	Side Elevation of Magnet Structure	208
145	Front Elevation of Magnet Structure	208
146	Portion of Elevating Bar	210
147	Side View of Commutator or Interrupter	210
148	Cross-section of Interrupter	210
149	A Pair of Brush Carriers	210
150	Perspective View of Brush Set	210
151	Elevation of Bank	214
152	Terminal Strips and Insulations	214
153	A Brush Set (Plan)	214
154	A Brush Set (Side View)	214
155	A Brush Set (Section)	214

FIG.		PAGE
	W. E. Co. PANEL SYSTEM—*continued.*	
156	Sequence Switch (part Section, part Elevation)	216
157	Sequence Switch (cross-section)	216
158	Sequence Switch, Insulating and Conducting Discs	216
159	Sequence Switch, Mounting Bracket for Brush Set	216
160	Positioning Device	216
161	Five-hundred-line Call Finder Panel Switch (Side Elevation)	219
162	View of Trip Rod	219
163	Subscribers' Lines on Call Finder Switch	220
164	Sequence Switch controlling Circuit	221
165	Metering Circuits, Subscribers' Line	224
166	Metering Circuits, Call Finder to Selector	225
167	Metering Circuits, Selector to Connector	224
168	Metering Circuits, Controller and Allotter	225
169	Register Circuit when changing from Manual to Automatic Working	229
	LORIMER SYSTEM:	
170	Diagram of One Section	233
171	General View of Hereford Exchange	234
172	Plan, Cylinder Switch, Register controlling Magnet and Mechanism	235
173	Side View of above	235
174	Plan of Cylinder Switch	236
175	Circuits of System	242
176	Consecution Controller Circuit	242
177	Decimal Indicator	240
178	Subscriber's Instrument Circuit	242
179	Subscriber's Instrument	242
180	American Automatic Co.'s Connector	244
181	American Automatic Co.'s System Circuit	245

FIG.		PAGE
	R. A. T. Co. SYSTEM:	
182	Sub-group of Ten Subscribers' Lines (Single-line Diagram)	249
183	Self-searching (Typical Diagram)	250
184	A Relay, De-energised	251
185	A Relay, Energised	251
185A	A Relay (Parts)	252
186	A Thermostat Timing Device Circuit	252
187	Thousand-line Trunking Scheme (Single-line Diagram)	253
188	Circuit, Calling Subscriber's-line Switch	260
189	Circuit, Called Subscriber's-line Switch	260
190	Circuit, Battery Feed for Calling and Called Lines	260
191	Circuit, Trunks to 1,000-line Group	260
192	Circuit, Ringing Unit	260
193	Circuit, Recorder Connector	260
194	Circuit, Recorder	260
195	Circuit, Marker	260
196	Circuit, Impulse Repeater	260
197	Operating Circuit of a Subscribers'-line Sub-Group	262
198	Grouping of Trunks on Final Switch	264
199	Operating Circuit of a Three-digit Final Group	264
	COVENTRY AUTOMATIC TELEPHONES LTD.:	
200	Selector and Connector	267
201	Bank Contacts	268
202	A Connector Unit Plate	269
203	Distributing Switch	269
204	Outline of Preselector Relay Switch	270
205	Multi-contact Relay	271
206	Leaf-spring Relay	271
207	Two-hundred-line Bay of Primary Equipment	272
208	Circuit, Subscriber's Line and Primary Control	280
209	Circuit, Primary Trunk and First Selector	280
210	Circuit, Local or Second Selector	280
211	Circuit Connector	280

DIRECTOR OF INDUSTRIES
LIBRARY.
13-JUL.1925
BENGAL.

LIBRARY 3 JUL 1925 BENGAL

Section 1

INTRODUCTION

The State of the Art.—Automatic switching of telephone lines in an exchange area is the only efficient and economical method of interconnection.

Manual switching has served its day well and faithfully, but it has depended for its success as largely on the organisation and drilling of the human factor as on the machine.

The traffic growth in large multi-office exchanges or areas: the necessity for the correct selection of suitable circuits for transmission efficiency: the varied and complicated services required: the prompt and highly efficient service called for by the public: the increasing difficulty of obtaining a good class of operator, owing to the opening up of other spheres of usefulness to women, among other reasons, have all helped to sound the death-knell of manual working—except in small offices—and proclaimed the necessity for machine switching.

Automatic switching is a long way beyond the experimental stage. It has proved itself capable of meeting all the conditions of modern business and social requirements, and that, in a manner, the manual system could not touch. Its untiring activities for 24 hours of the day, its reliability, its exactness and correctness of operation, its capabilities for meeting abnormal rushes of traffic, all place it on a platform apart, as the only hope and stay of the business and social community.

Financial and political reasons in the past have greatly hampered its development—and that, particularly, in the United States of America, which is usually held up before us as a pattern of telephonic efficiency. The American Telegraph and Telephone Co., commonly called the "Bell," has, until quite lately, refrained from installing and left the development of the automatic system to the "independent" operating companies.

The system of the Automatic Electric Co., of Chicago, the "Strowger," is practically the only system used in the States. But the experience of that Company has been unfortunate in many respects, due to external influences. With amazing energy and foresight it has developed the somewhat crude and cumbersome system, invented by A. B. Strowger in 1889, into a comparatively simple and highly efficient system, capable of meeting all traffic conditions. For this Mr. A. E Keith, their chief engineer, is largely responsible. Their system has been installed in many of the great cities in opposition to the "Bell" interests, but in some, *e.g.*, San Francisco, Chicago, Buffalo and Los Angeles, the opposition has been too much for them and these automatic installations, the largest installations in the States, have been acquired by the Bell interests, and in some cases the automatic equipment has been abandoned.

The Strowger system has been installed and is appreciated in nearly every country of the world.

The American Telegraph and Telephone Co., while refraining from introducing the automatic system commercially, have been for some years, through the Western Electric Co., developing a system technically, and, it is believed, will shortly begin replacing the present manual plant. Their "rotary" system of machine switching is well known in this country. It is expected, however, that they will put their "Panel" system with 500-line switches on the market soon.

The Automatic Telephone Manufacturing Co. of this country use the Strowger (Auto-

matic Electric Co., Chicago) system and have lately introduced a self-propelled rotary line switch, instead of the Keith line switch, which greatly enhances the value of their system.

Siemens and Halske, in Germany, and Siemens Brothers & Co., in this country, use a modified Strowger design. The latter company have made many important modifications, and now possess a very original and efficient system.

The Relay Automatic Telephone Co. have made a departure from the beaten track, and advocate the use of relays *only* for installations of all sizes. They have a number of small exchanges in operation.

The Lorimer system has been in use in some towns in Canada for a considerable number of years, and it has been fitted in Hereford in this country.

The work of the North Electric Co. is not known in this country, but their auto-manual (semi-automatic) system has been installed in a number of towns in the United States.

The Coventry Automatic Telephones, Ltd., are about to exploit this system and have arranged to instal an exchange in Dundee.

The American Automatic Telephone Co.'s system is not known in this country.

The use of large instead of small switches is likely to be an important and momentous question in the near future.

The Strowger system uses 100-line switches, with the line contacts in 10 levels of 10 sets in the arc, a set of wipers being stepped up to the required level.

The Western Electric Co. use a 200-line switch with 10 levels of 20 contacts in the arc. There are 10 sets of brushes, the brush associated with the required level being tripped into engagement.

In the W. E. Co.'s panel system the switch has five groups of 100 sets of terminals, with a set of wipers associated with each. The wipers, of a particular set, are tripped into engagement, and then stepped over line contacts.

The Relay Automatic Telephone Co. is advocating the use of relays only for the connection of a calling line to one of a group of trunk lines.

In the Strowger system, obviously, a calling line can have only access to 10 sub-groups each of 10 lines of outgoing trunks. The traffic, therefore, from a number of lines must be measured to suit the carrying capacity of 10 outgoing trunks. There is thus sub-division of the outgoing trunks into sub-groups of ten lines.

In the Western Electric Co.'s system there may be sub-division into groups of 20 outgoing trunks as there are 20 contacts in a level. In their panel system there are 500 contacts, and therefore five groups of 100 trunks available to each incoming line.

The sub-groups of outgoing lines, as above, are 10, 20 and 100, to which each incoming line has access.

It is known that the larger the group of lines, the greater is the traffic carrying capacity of each line of the group; therefore a 20-line group is more efficient than a 10, and a 100-line group is very much more efficient than either.

Against this efficiency there has to be placed the greater cost of the switches, and their maintenance, and the increased difficulty of routing a call.

It is possible that small switches, in combination with a special sub-division of the trunks, may be found quite satisfactory.

The problem is one of the most interesting before telephone engineers at the moment.

Section 2

A FEW DEFINITIONS

The Exchange.—Originally the term exchange was used to designate the intercommunication system over which a subscriber had the right of connection for a given sum paid. The exchange was divided into switching rooms for the convenience of the exploiter, or provider of the system, and the telephone numbers were continuous over the whole area. As the number of subscribers grew this became impracticable without using numbers of many digits, which were difficult to remember or repeat. The capacity of the manual switch board was, therefore, adopted as the highest telephone number, and these numbers were prefixed by the names of the different switch rooms or offices. The switch room, or office, was very generally known thereafter as the exchange.

With the advent of the automatic system of working, it seems advisable to revert to the original definition, as the telephone numbers now run consecutively over an area, and the system is again divided into switch rooms, or offices, to suit the economical distribution of the plant.

We have, therefore, a *sub-station* at the subscriber's office, which may consist of one, or a plurality of direct lines, or a small switchboard.

An *office* which is a sub-division of the main plant.

An *exchange* or multi-office system which has a common numbering scheme, and over which full interconnection is obtainable for a given sum to be paid. Exchanges are connected together by trunk or toll lines, for which an extra fee is to be charged.

The Plant.—A preselector is a switch that automatically selects an idle line of a group when the receiver is lifted, *i.e.*, prior to any digit impulses being sent. It is therefore sometimes called a pre-digit or non-numerical switch. It may be either a calling-line finder, *i.e.*, has a backward hunting motion, or a trunk finder having a forward hunting motion.

Secondary preselectors are generally used in combination with the former, which are, therefore, known as *primary preselectors*.

The primary preselector, when one is associated with each calling line, is frequently called a *line switch*.

Owing to the use of comparatively small groups of lines and the consequent sub-division of the trunk group, the number of trunk lines and first digit switches to which the trunks are wired is excessive. Second preselectors are therefore interposed to reduce the number of first selectors required. The second preselectors may be of any of the forms described for first preselectors.

The Strowger-Keith switch is a true preselector, because an idle trunk has already been assigned to a potential calling line. When a trunk is taken into engagement the master switch moves all plungers of calling lines to a point opposite the next idle trunk. The Siemens switch hunts for an idle trunk after the receiver is lifted.

In the Western Electric Co.'s system the preselector is of the call-finder type, and hunts for the calling line after the receiver is lifted.

In the Relay Automatic Telephone Co.'s system the relays instantly connect a calling line with an idle trunk. Common relays control the instantaneous operation of the connecting relays.

Selectors or Group Selectors.—These automatically select an idle line in a group of lines

corresponding to the impulses composing a digit sent from a dial sender. . These have usually 10 levels which are 10 sub-groups of trunks, corresponding to the digits 0 to 9.

In an installation there may be first, second and third selectors, or even a fourth according to the size of the exchange. One selector gives a capacity of 999 lines, two selectors 9,999, and three selectors 99,999. The two last digits in each case are taken by the connector.

In the Western Electric Co.'s selector the first and second thousands, and the like, are taken by the same selector.

Connectors.—These are sometimes called the *final* switches because they are associated with the two final digits of a subscriber's number. One digit controls the stepping up of the wipers to a particular level, or group of ten lines, in the Strowger switch, and the last digit steps the wipers round to the particular unit.

In the W. E. Co.'s 200-line final switch, the tripped wiper connects in the left- or right-hand half of the 20 contacts of a level, according as the digit is an odd or even number.

The mechanical construction of a selector and a connector are very similar.

A selector is sometimes caused to respond to two digits for the two movements of the shaft, and is then called a *selector-connector*, or a *two-digit selector*.

A connector is sometimes caused to automatically select an idle line in a group chosen by two digits—as in P.B.X. working. It is then called a *rotary connector*.

The selector and connector are provided with *wipers*, brushes or arms, which sweep over the contacts to find a desired line.

The contacts are arranged in *banks* made up of a plurality of rows or levels. The levels have usually three contacts per line, which may be grouped in parallel lines, or the two talking contacts may be one over the other, in one bank, and the test contact in another bank.

The first preselectors in the Strowger system are arranged in 100-line panels, or units, with the connectors for the same subscribers' lines fitted in the rear. Usually ten are fitted on each 100-line unit with capacity for 15, to allow for traffic growth, and for trunk-offering and testing connectors.

Lines.—A line is a complete metallic circuit and is made up of an A and a B wire. The A wire is that which is connected to the earthed, or positive, pole of the battery when the line is idle. The B wire is connected to the negative pole of the battery.

When the line is between switches in the same office, there is a third wire called the C wire, or the guard wire.

The designation of the lines interconnecting apparatus at different switching stages, whether near together or wide apart, is somewhat confusing. The American generally speaks of these as *trunks*, which practically is equivalent to our *junctions*. The author pleads guilty to using both terms for the same thing.

The term trunk or junction is therefore used for circuits between apparatus at one stage and apparatus at another stage. For example, the circuits between first and second preselectors, second preselectors and first selectors, first and second selectors, second and third selectors, and third selectors and connectors, are all trunks or junctions. When any of these circuits are between two offices, they are termed *inter-office trunks or junctions*.

Very commonly the lines between exchanges in this country, and for the use of which an extra charge is made for each conversation, are known as trunks. For these the American terms *toll line* or *long-distance line* is used.

Other terms will be defined when dealing with particular systems.

Fig. 1.

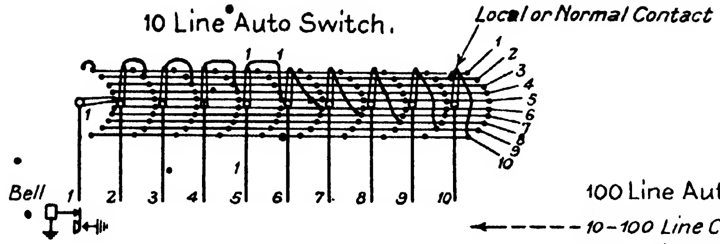
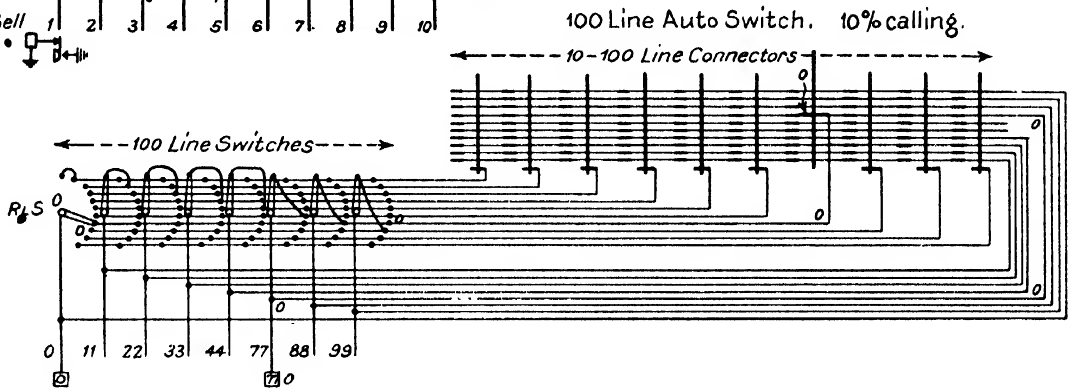


Fig. 2.



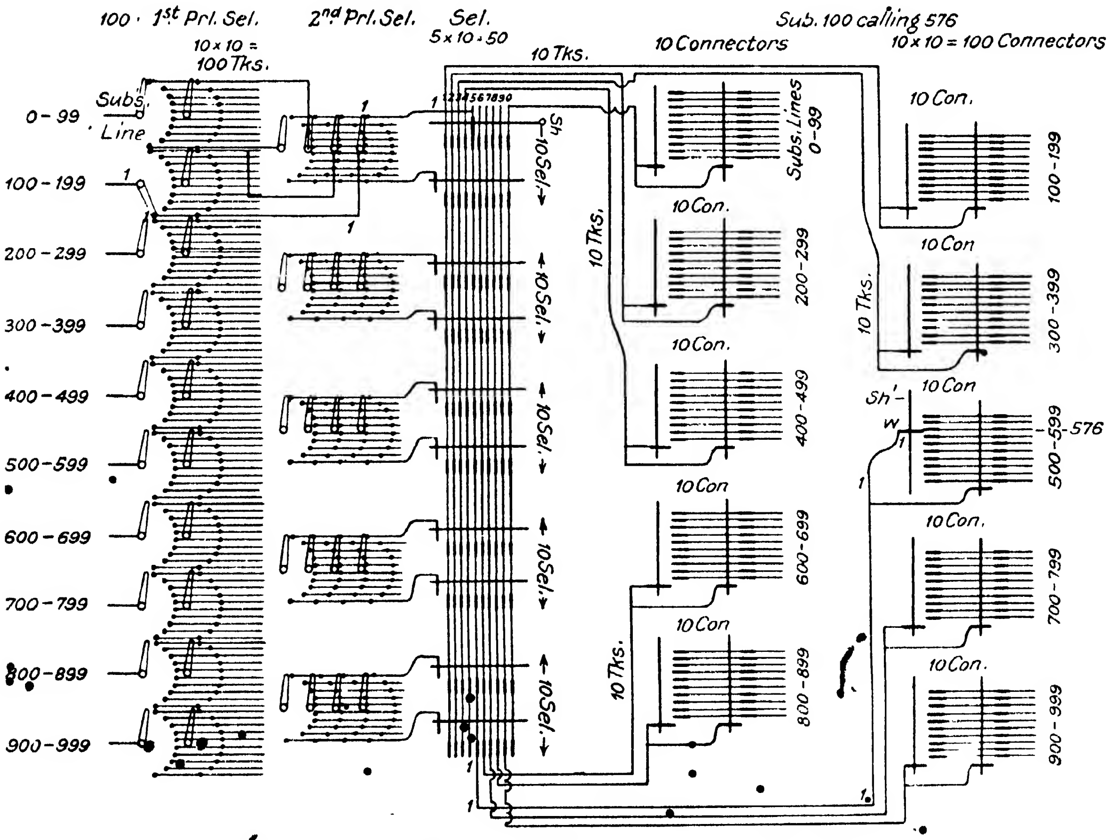


Fig. 3.—1,000 Line Auto-Switch with Double Preselection.

Section 3

FIRST PRINCIPLES

The object of the telephone exchange is to connect one of a group of lines to any other one of the same group. In manual telephony an operator, in response to a signal, connects one end of a flexible cord to the caller's line and, after learning his requirements, connects the other end of the same cord to the line of the party desired. When conversation is finished, a signal is given to the operator, who removes the temporary connection between the two lines. The automatic switch is provided to make and sever connections without the human intermediate agency by electromagnetic means, under the control of the party desiring the connection.

In a group of 10 people desiring automatic intercommunication, 10 switches will be required (Fig. 1), each having 10 sets of contacts and a wiper, or flexible spring, capable of being moved step by step by electromagnetic means, according to the number of times the magnetic circuit is opened and closed. In a metallic circuit system there will be three layers of 10 contacts, arranged in 10 sets of three. Two contacts of a set will be associated with the talking circuit, and the third will be the test circuit by which, when a line is busy or engaged, the circuit to the wipers will be held open, and when the line is idle, and therefore ready to receive the offered connection, the wiper circuit will be completed to join the two lines together. There are three wipers corresponding to the three contacts or terminals.

An incoming line of the group is connected to the line wipers of each switch. In the line circuit is a relay which responds to impulses sent by the caller, which repeats these to the stepping electromagnet. The corresponding terminals of all the switches are connected together by insulated wire. Each set of three wires is connected to its associated subscribers' line through a normal contact, represented in the diagram by an extra contact placed at the beginning of the arc of contacts, on which the wiper normally rests. It will be noticed that this contact is connected to a different multiple line on each switch. When the wiper moves from this contact, the multiple line is entirely insulated, and should, therefore, test as busy. The caller's multiple must not be made use of whilst he is seeking connection with another party whose multiple will test idle if the wiper of his switch is on its local, terminal, or normal position.

If No. 1 desires to talk with No. 5, he will lift his receiver, and by pressing a key, or by other suitable means, open his line circuit five times. His line relay will cause the electromagnet to step the wipers round to the fifth set of contacts, when, if the line is idle, connection will be completed with the party called. The called party may be rung in any suitable manner.

When the receiver is replaced after conversation, a release magnet will allow the wiper to be rotated to the normal position.

Fig. 4 shows a small switchboard for five lines. A connector is associated with each line. Each two-wire line connects through relay contacts to the wipers.

All the lines of the group are multiplied together on the banks of each switch, and the test circuits are similarly multiplied on other (the upper) banks. From the line side of each switch three wires are carried to, and attached to, the multiple wiring, two wires to the line multiple, and one to the test. When a call is made, say by No. 01 calling 05, No. 01 wipers

are rotated to the fifth set of terminals on the banks, when connection is made over the multiple to the three wires connecting directly with the line of 05 ; that connector then being tagged on to the line, but insulated therefrom. Both lines are made busy to other calls.

In a 100-line exchange the connections would be similar, but the connector would have vertical and rotary movement.

To increase the capacity of the installation it is necessary to increase the size of each switch, and again provide one for each line. The usual way of increasing the size of such a switch is to provide a plurality of levels (*i.e.*, 10 sets of three terminals), placing them one over the other. An additional electromagnet is required to first step up the wipers to the required level of tens, and then the wipers are rotated to the required unit as before.

The tens digit impulses formerly were sent over one wire of the subscriber's line, then one impulse over the other to change over the circuit to the rotary magnet, and then the units impulses were sent over the former wire.

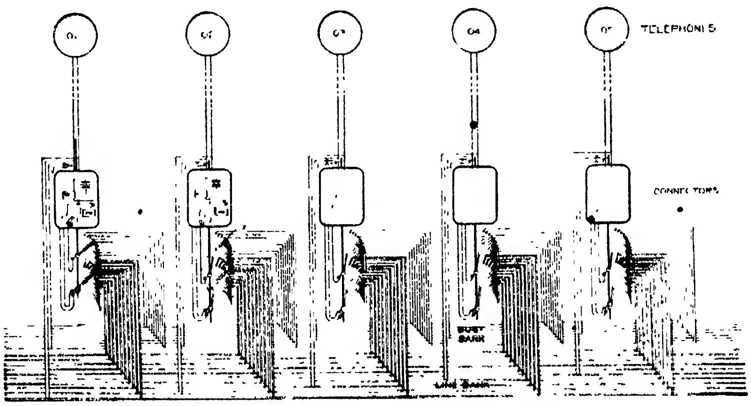


FIG. 4.—5-LINE AUTOMATIC SWITCH

As the connector for 100 lines is an expensive piece of apparatus to associate with each subscriber's line, it has become the standard practice to associate a cheap rotary switch with each line, these having access to 10 100-line connectors. Such an arrangement is shown in Fig. 2. The line switch RLS is drawn in the same manner as the 10-line connector (Fig. 1), but in this case it is a rotary preselector, *i.e.*, when the receiver is lifted the wipers, under interrupted electromagnetic control, continue to step from terminal to terminal until an idle line is found, independently of any action of the caller. When an idle connector is found, they come to rest, so that the calling line is automatically extended to the wipers of a connector. Each connector has the total lines multiplied to its banks, there being 10 levels of 10 sets of terminals, with the corresponding terminals on each switch multiplied together. In Fig. 2 line No. 0 is supposed to have called, and the line switch has found an idle line to a connector on the seventh terminal. The tens digit impulses are now sent from the dial impulse-sender on the subscriber's instrument, and the wipers are raised to the corresponding level, *e.g.*, 7. The units digit impulses are then sent and the wiper rotated step by step to the corresponding terminal, *e.g.*, 7. This terminal has its multiple wiring connected back to the subscriber's line 77, as indicated by the symbol 0. When the receiver is replaced, the

line switch wipers return to normal, and the connector wipers first are rotated counter-clockwise under spring control, and then fall by gravity to the normal position.

In a 1,000-line exchange there may be 10 groups of 100-line switches as just described, each group having access to 10 first selectors, each level of the banks being multiplied to 10 100-line connectors. In this case there would be 100 first selectors. As these are expensive switches, it is found more economical to fit second preselectors, and reduce the number of selectors to 50 to 70 as required.

Fig. 3 shows the use of first and second preselectors in a 1,000-line exchange. The first vertical row of switches represents 10 groups of 100-line switches or first preselectors. The second row represents second preselectors, which reduce the trunk or interconnecting lines from 100 to 50. The latter figure has been chosen simply because it can be readily indicated in diagram, to which generally the arrangement does not lend itself. Two 100-line groups of first preselectors are not merged into one group of second preselectors, as shown, but all the lines from the first switches are distributed over all the second switches according to a special formula, which is described elsewhere. To simplify the diagram also, the selectors are shown lying on their sides, with the shafts horizontal instead of being vertical. Each of the ten levels connect to 10 connectors, each 10 being associated with a different 100 lines of the total 1,000.

We will assume a call being made by No. 100 for No. 576. The receiver having been lifted, the line switch, as shown, has found an idle line on the tenth terminal, and extended the calling line to the wiper of a second preselector, which finds an idle line on the first terminal, so that the callers line is extended to an idle selector without any further act on the part of the caller. He now sends the hundreds digit five by the impulsing dial, and the shaft *sh* is lifted step by step to the fifth level. The wipers then automatically, and without his control, pass from terminal to terminal until an idle line to that particular group of connectors is found. The tens digit is now called, and the shaft *sh'* is stepped up from the normal position to the seventh level. The units digit is now called, and the wipers are rotated under dial control, until they reach the sixth terminal, where they come to rest and join the lines together. The circuit just described is identified by the symbol 1. When the receiver is replaced, the line switches return to normal, as before described. The second preselectors may or may not return to normal, depending on the system employed. The selectors return in two steps in the same manner as the connectors.

In a 10,000-line system, the arrangement is similar to that last described, with the addition of a group of selectors between the second preselectors and the selectors formerly shown. The new selectors are now known as the first selectors, and those shown in Fig. 3 the second selectors. The multiple of the first selectors consists of 10 levels or groups of outgoing trunks, each connecting to a different set of second selectors each associated with a different 1,000 lines of the total. The multiplying of the second selectors to connectors, and the multiple of subscribers' lines on the latter, is as before described for Fig. 4. A caller now first dials a thousands digit to operate the first selector, then a hundreds digit to actuate the second selector, then tens and units digits on the connector.

In a 100,000 line, or five digit (99,999), system (Fig. 5) still another selector is introduced between the second preselector and the former first selector. The new selector now becomes the first selector, the former first the second selector, and the one preceding the connectors the third selector. The system may consist of 10 different offices, each with a capacity of 10,000 lines, or two or more 10,000 units may be in one office. The first digit

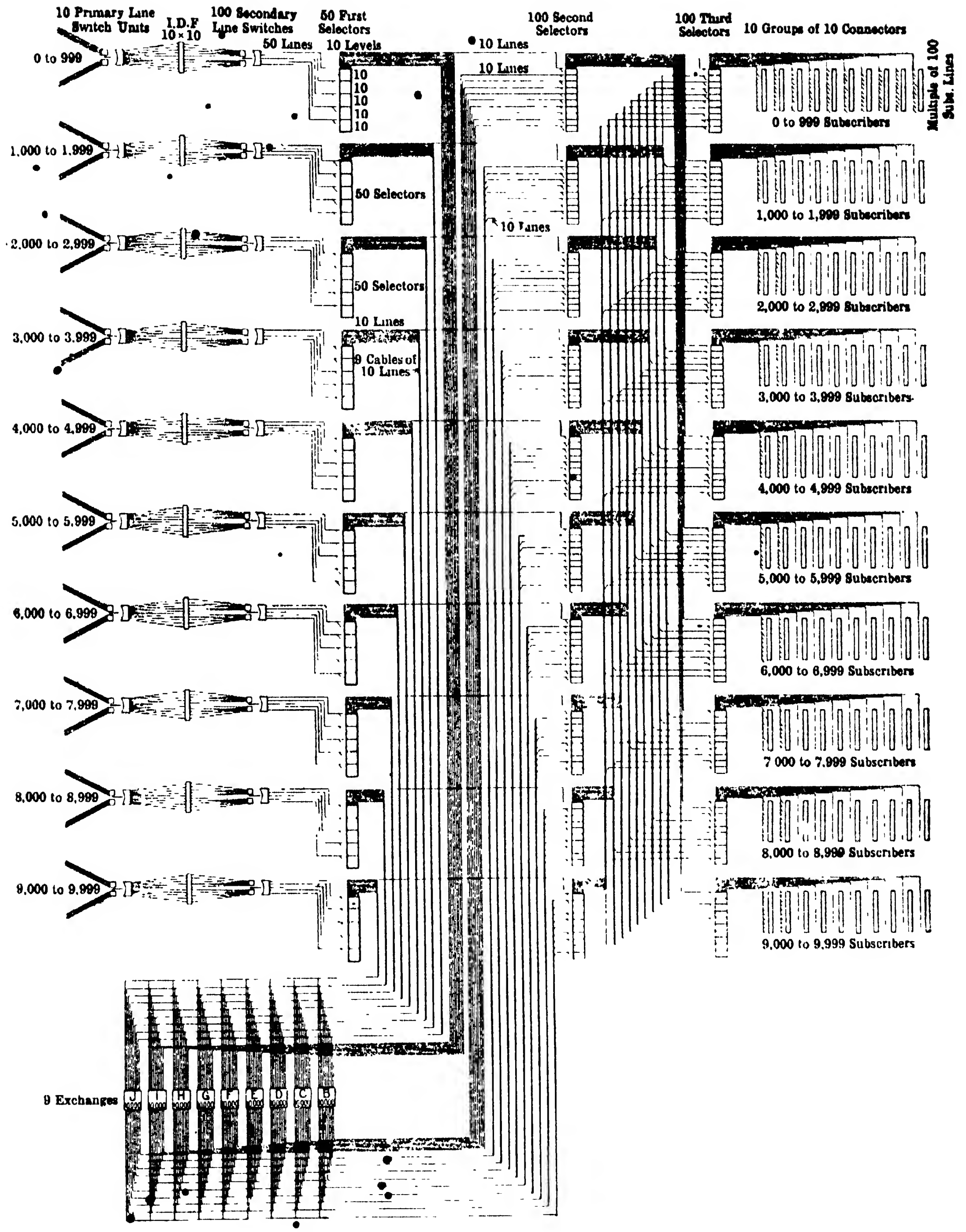


FIG. 5.—LAYOUT OF 100,000-LINE SYSTEM.

called selects a 10,000-line unit, the second a 1,000-line unit, the third a 100-line unit, and the fourth and fifth the tens and units.

The switches shown and described are peculiarly suitable for a decimal system, but as will be afterwards described, the switches may be arranged for non-decimal calling. The arrangements shown may be modified by wiring expedients to give a greater number of switches when required to cope with a heavier calling rate. For example, the third selectors may have the multiple length on the banks divided and so give access to 20 connectors, or each multiple length of circuit may be divided one by one as required to meet traffic growth. For example, the multiple connected to No. 1 terminal on a level may be halved, and each half joined to a connector, when the connectors for one group of 100 lines will be increased from 10 to 11. No 2 terminal multiple may then be divided similarly, and the connectors increased to 12, and so on. Similarly, the first selectors with 10 lines to each group of second selectors cannot be sufficient for both a 1,000 and a 10,000 line exchange as shown in the diagrams, but the multiple lengths may be divided in the manner described to increase the second selectors to any number required for the traffic.

Instead of attempting to increase the number of trunks from the first preselectors, it is generally preferred to decrease the number of subscribers' lines in the unit. In very busy exchanges, the Strowger line switch unit can be used as two 50-line groups.

Section 4

DIAL IMPULSE-SENDERS ON SUBSCRIBERS' INSTRUMENTS

The automatic switching apparatus of an exchange responds to impulses sent from the subscribers' offices.

In the early installations, which were worked on what was known as the three-wire

FIG. 6. A. T. M. Co. (A. E. Co.) DIAL SWITCH.

FIG. 7. INTERIOR OF A. T. M. Co. IMPULSE DIAL.

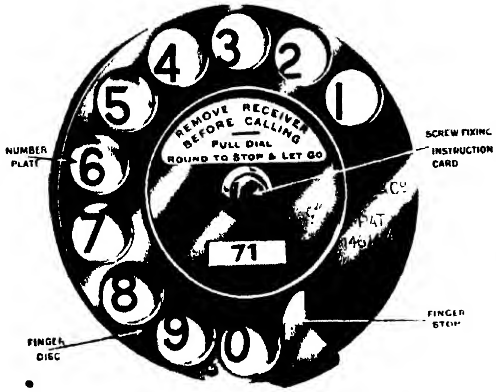


FIG. 8. SIEMENS' TELEPHONE DIAL SWITCH (FRONT VIEW).

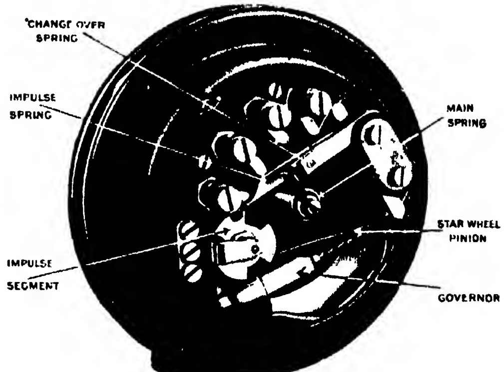


FIG. 9.—SIEMENS' DIAL SWITCH (REAR VIEW).

system, the impulses were sent from the sub-station by a succession of short earthings of one wire of the metallic circuit line, to step a switch either vertically or in a rotary direction. Each train of impulses was followed by an earthing of the opposite wire for circuit-changing purposes, to bring into circuit the magnets necessary for the succeeding train of impulses.

In all modern systems the earth is eliminated and the impulses are now sent by interrupting, or momentarily opening, the metallic circuit, completed when the receiver is lifted.

In the Strowger system, the duration of an impulse is from the beginning of a break in the circuit, over the re-make, to the beginning of the next break. Until recently the duration of make and break were about equal, but in the later dials of the A. T. M. Co., the break is now ·61 of the impulse instead of ·5. The Siemens' break is about ·33 and the W. E. Co. about ·12.

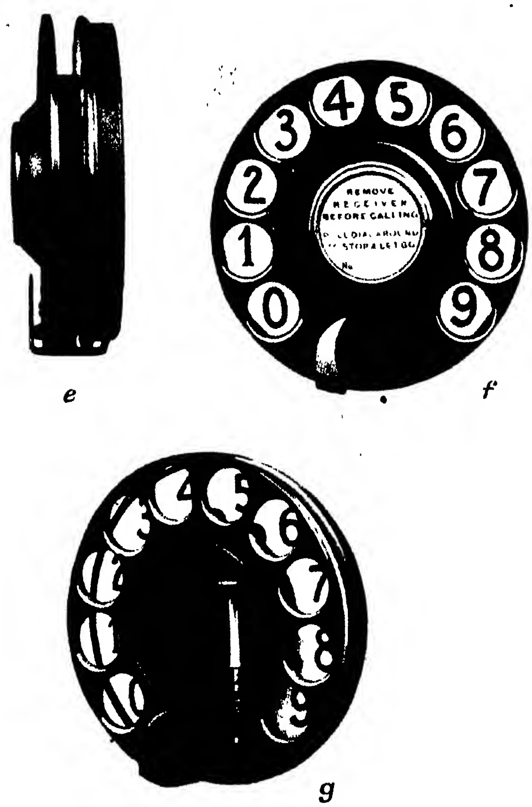


FIG. 10.—W. E. Co.'s DIAL.

The circuit-changing is now effected by special relays, which energise in the local circuit of the line or impulse relay, when the receiver is lifted. Such relays are made slow to de-energise, usually by having a mass of copper surrounding the end of the core, which acts as a single turn to prevent the rapid demagnetisation of the core. These relays energise immediately after the impulse relay, and remain energised whilst the former is de-energising and re-energising in response to the impulses, but de-energise when the interruption is longer than an impulse break, or opening of the circuit.

This is not the invariable method of changing over. In the Western Electric Co.'s system, a long interruption of the circuit at the end of a train of impulses allows a relay, made slow to energise, to energise and bring about the change-over to another register. Other variations will be pointed out later.

In the early installations, the impulses were sent by keys or push buttons, a plurality of keys being provided, one for each digit of the hundreds, tens and units. These proved unreliable, as the subscriber could not be depended on to depress a key the correct number of times, according to the digit.

To the Strowger Co. of Chicago belongs all the credit for evolving the dial impulse-sender, which is now universally adopted. It is practically fool-proof, and eminently suitable for use by the general public. Externally it is a rotatable disc with a series of holes near the outer edge through which figures which represent the digits appear. At a point on the path of rotation is a fixed stop. A finger is to be placed in the hole corresponding to the digit to be called, and the dial plate rotated clockwise until the finger comes against the fixed stop. The dial cannot be rotated counter-clockwise. The rate of pull is of no moment, as the impulses are sent out as the dial returns to normal under spring control.

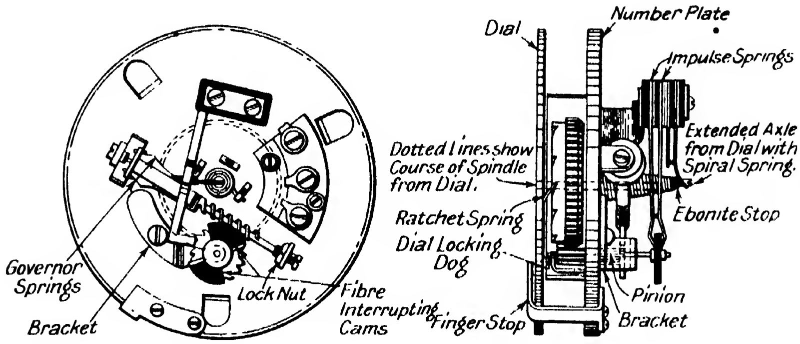
Illustrations of several dials are given as used by different companies, but all have the same fundamental features.

Figs. 6 and 7 show the dial as made by the Automatic Telephone Manufacturing Co., of Liverpool, Figs. 8 and 9 the dial as made by Siemens Brothers & Co., of Woolwich, and Fig. 10 three views of the dial made by the Western Electric Co., of Woolwich. In the two former, the figures are arranged 0, 9 . . . 1 clockwise, the second having a greater interval between 1 and the fixed stop for reasons to be explained. The W. E. Co.'s dial is arranged 0, 1 . . . 9 clockwise, for reasons also to be explained.

Section 5

DIAL ADJUSTMENTS

Automatic Telephone Manufacturing Co.'s dial. Figs. 11 and 12 give a better idea of the mechanical arrangements and the relationship of parts, the more important parts being named on the drawing.



A. T. M. Co (Strowger) Dial.

Fig. 11.—Rear View with Connecting Strips removed. Fig. 12.—Side View with Terminals removed.

The following details of the adjustments and construction will be of interest :—

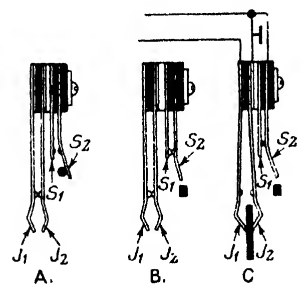
When the dial plate is rotated the ratchet spring should fall into the second ratchet tooth just as the front of the finger stop passes through the centre of the first finger hole.

The conical main spring should have between one and a half and two turns counter-clockwise. The main spring bushing should raise the front shunt about $\frac{1}{32}$ of an in. from its opposing contact on the impulse spring. The shunt spring should be so adjusted that it does not cut into the main spring bushing, and should follow the impulse spring $\frac{1}{32}$ of an in. when in contact with it. When the dial is operated the main spring must not bulge out and touch the governor hub and cause slow return.

The impulse springs should break contact at the instant the fibre cam passes through

the tips of the springs. The tips of the springs should not be opened in order to reduce the friction, but at the same time they should not be so close as to short circuit the contact points. Daylight should just be visible between the tips.

The tension of the springs should be such that the inner spring will follow the outer one until its end lines up with the upper side of the fibre cam. The mate spring should



A. Normal Position.	B. Dial pulled away from Normal Position.	C Dial Free to Return.
"J_1" and "J_2" in Contact, "S_2" open.	"J_1," "J_2" and "S_1," "S_2" in Contact.	Interrupter Springs "J_1" & "J_2" open circuit. "S_1," "S_2" in Contact

Note – "J_2" & "S_1" are assembled in contact

FIG. 13.—A. T. M. CO. DIAL IMPULSE SPRINGS. POSITION OF IMPULSE SPRINGS DURING OPERATION, &C.

behave similarly. The outer spring should follow the inner one when it is deflected until its end lines up with the lower side of the fibre cam.

The impulse springs should be deflected equally when the cam is rotated by the finger plate. They should be free of the cam centre and only touched by the cam wings.

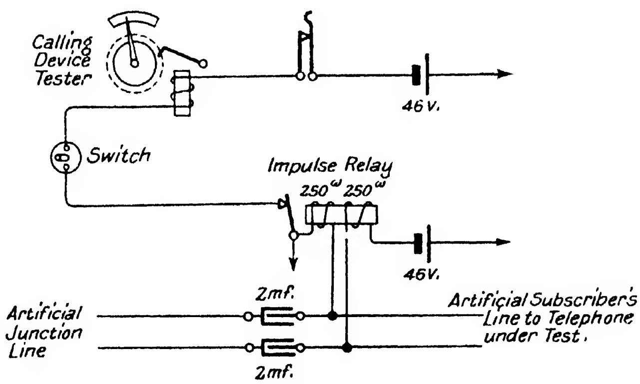


FIG. 14.—A. T. M. CO. DIAL TESTING CIRCUIT FOR USE IN WORKSHOP.

The contacts are to be operated as shown in Fig. 13 at A, B, C. The shunt spring (to short circuit the telephone) should not break prematurely. It should break just after the impulse springs have closed at the end of the digit.

The most efficient operating speed is 10 impulses per second with a maximum of 12 and a minimum of eight. The speed of dials should be checked on the *dial speed tester* fitted on the test desk. Such testers should be fitted also where dials are to be adjusted. A suitable circuit, as used by the British Post Office, is shown at Fig. 14.

The dial speed tester can be tested at intervals against a telegraph inker as follows :—

An ink mark to correspond in length with four seconds is made on a tape. A fourth of this is to be taken as a standard. A record should be taken, from a dial of 10 impulses from the digit 0, on a slip. The length from the beginning of the first break to the end of the last break, when compared with the standard length of tape, will give the speed of the dial. The dial should be adjusted until the two lengths are equal. The dial will then be running at a speed slightly slower than 10 impulses per second. The dial should then be tried on the dial speed tester and, if the latter is not correct, the length of the pendulum should be adjusted accordingly.

To adjust the speed of a dial the governor wings should be slightly bent with a special tool close to the governor balls, so that the adjustment will bring each ball to exactly the same distance from the inside rim of the governor cup. The governor wing must be adjusted so that the governor balls do not rub on the sides of the aluminium hub notches. There should be about $\frac{1}{64}$ of an in. play between the governor shaft ends and the agate bearings, with which each bearing screw is provided. Care should be taken in turning the bearing screw into the lug at the worm end of the governor not to crush the agate thrust bearing. The screw should be held tightly in the lug by the clamping nut. The bearing screw holding the governor cup should be in exact line with the governor shaft. The aluminium hub should not be rotated about the governor shaft as a slight pull is the proper test for loose aluminium hubs. To examine the governor generally, pressure should be taken off it by rotating the finger plate and holding it. Attention should be given to end play, correct shape and tension of the wings, and clearance between the governor and main spring.

The fibre cam should be set so that its mid line is approximately at right angles with the line of the governor shaft. If the fibre cam is not set correctly, the pinion will have to be remeshed with the ratchet gear. This can be done as follows :—

Remove screw from the bracket which holds the pinion, turn the dial so that the dial locking dog is free from the pinion, and unmesh both the ratchet and governor gears. Turn the fibre cam to the proper angle, remesh the gears and replace the screw. Care must be taken not to rotate the ratchet wheel while the gears are unmeshed.

The fibre cam should be rigidly locked when in the normal position, but if there is looseness between the worm wheel and the pinion, or if the locking dog is not properly adjusted, this will not be the case, and the fibre cam will slip out of its normal position when tested by hand and remain between the impulse springs. A test should be made to see if the cam is fixed as it should be, but as it is set permanently into a rectangular base, only a slight pressure should be applied to it in order to avoid injury.

One slightly bent worm gear tooth may cause the dial to stick. The pinion should be placed so that the tooth of its worm gear will engage about four-fifths of the depth of the governor shaft gear. The dial locking dog should strike exactly in the notches of the pinion.

The ratchet spring should drop into the ratchet gear notches when the dial is lightly forced back from 1 as rapidly as possible.

Section 6

DIAL. SPECIAL FEATURES

The Siemens' Dial (Figs. 8 and 9).—A definite minimum interval between trains of impulses is secured. Where this is not provided short trains of impulses, such as 1 . 1 . 1, may arrive before a free selecting switch has been found. To effect this interval the dial switch is provided with two trains of gears, the governor train and the impulse train. The ratchet wheel driving the governor train is fixed to the finger plate and driven thereby. The impulse train is driven by a pawl mounted on a disc, the disc being located between the driving wheels of the respective trains. The pawl referred to engages the internal teeth of the ratchet wheel, thus transmitting the drive to the disc, and subsequently to the impulse train in one direction only. The disc is further provided with a slot, the ends of which engage a pin on the toothed wheel of the impulse train so that the governor comes into action some time before the impulse train. When the dial is released the governor starts at once, but it is only after the pin has passed to the other end of the slot that the impulse train is operated and impulses begin. No matter how quickly the dial is operated, this interval must occur between successive trains of impulses.

The governor and the main spring have been made the subjects of special study and design, to give great regularity in the timing of the impulses. The impulse springs are normally held closed by the fibre, opening under their own tension. This assists greatly in securing exact impulses.

W. E. Co.'s Dial (Fig. 10).—The finger disc is mounted on a shaft and held against a stop by a spiral spring. When displaced from normal the disc returns under the tension of the spiral spring, but does so at a predetermined and constant speed under the influence of a governor. A special loose disc at the centre is so fitted that the finger disc may be moved forward as quickly as desired, the governor being disconnected.

The finger disc carries a series of small teeth and one large tooth, which operate in passing a contact lever: the contact lever opens a contact, included in the line circuit, but only on the return movement of the finger disc. The short interruptions of a train of impulses are always followed by a long one to mark the change over.

Section 7

INTERCHANGEABLE DIAL

New Dial Impulse-sender with Interchangeable Impulse Wheel.—The joint property of A. T. M. Co., Siemens Brothers and W. E. Co. (Fig. 15).

The different systems in use require different ratios between the times of making and interrupting the current impulses, and also a variable amount of lost motion in the impulse transmitting device at the beginning of each train of impulses.

This dial is constructed so that the cam or impulse wheel is interchangeable, and can be readily removed and replaced by one adapted to meet the particular requirements of the system in use, this interchange being made without affecting any other part of the apparatus.

The teeth of the cam wheel and the pawl operating the contact springs are formed so as to provide the required ratio between the times of making and breaking the circuits, and the design also ensures that the pawl leaves the teeth of the wheel without causing any vibration of the contact springs.

The cam wheel is provided with long teeth adapted to provide a considerable amount of lost motion at the beginning of the transmission of each train of impulses. Normally, the pawl is held radially to the wheel; when the cam wheel is rotated by the operation of the finger dial the pawl is rotated through a considerable angle before it rides over the end of the tooth with which it has been in engagement. If the teeth are close together the pawl cannot slide far down into the space between the teeth during the continued rotation of the cam wheel by the finger dial; when, however, the hand is removed and the dial rotates in the reverse direction, the pawl will be displaced so as to extend more deeply into the space in which it happens to lie. When the pawl has regained its radial position, the continuation of the rotary motion causes it to move upwards out of the space which it has entered until it reaches the level of the top of the teeth, when the first current impulse will be transmitted. The considerable extent of the motion of the pawl from the release of the finger until the beginning of the first impulse corresponds to a comparatively long interval of time.

The shape of the teeth of the cam wheel determines the character of the impulses transmitted by the apparatus. For instance, if the end of a tooth is broad, the current will be interrupted for a longer time than if the tooth is narrow. All the teeth need not have the same form; for instance, a very broad tooth will cause a longer interruption at the beginning or end of a train of impulses.

Fig. 15 A is a view of the dial as seen from the back, B is a central section, C and D show a modified construction of the pawl.

Schedule of parts with reference to the drawings:—

1. Base plate.
2. Spindle, free to rotate in 1.

2′. Collar to prevent axial play, even when 3 and 4 are removed.

3. Number plate.
4. Finger dial, fitted at one end of 2.
5. Clamping ring fitted in recess of base plate. Holds number plate in position against 1.
6. Cam wheel with long teeth, fitted to rear end of 2 and made readily removable.
7. Pawl operated by 6. Normally held radially to the teeth and enters deeply between the teeth.

8. Screw fixed to 1, about which 7 rotates.
9. Spring.
10. Stud secured to 7, on which 9 presses.
11. Clock spring to counter rotate 2.
12. Casing to which one end of 11 is fixed (other end to spindle).
13. Ebonite stud on pawl.
14. Spring contact with which 13 engages as the pawl rides over the end of each tooth during the return movement of cam wheel 6. Thirteen momentarily lifts 14 from 15 without springs vibrating.

15. Mate contact spring.

16, 17, 18. Contact springs to short circuit receiver.

19. Stud in cam wheel 6 to operate above.

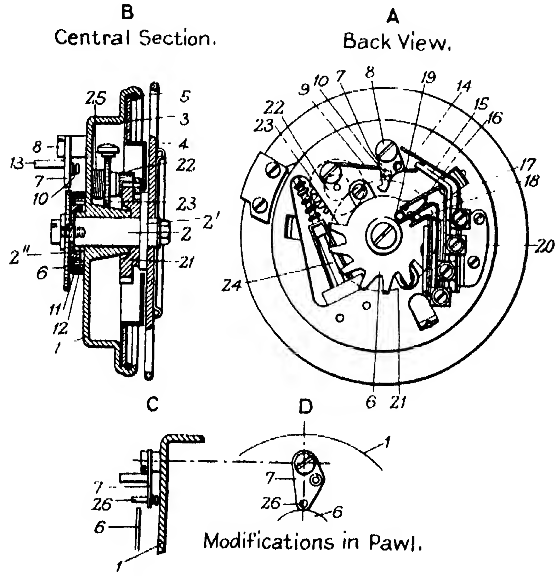


FIG. 15. DIAL WITH INTERCHANGEABLE CROWN WHEEL.

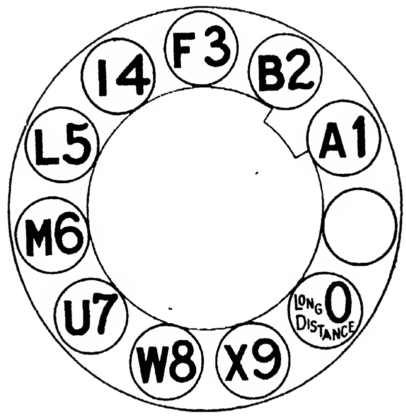


FIG. 16. DIAL PLATE WITH FIGURES AND LETTERS.

20. Bracket on plate 1 carrying above 16 to 19.
21. Toothed wheel on spindle 2.
22. Pinion with which 20 engages.
23. Governor wheel on spindle of 22.
24. Governor to control rate of interruptions.
25. Spindle spring attached at one end to wheel 23 and wound round spindle of pinion 22. This spindle can rotate freely inside the spring 25 when the dial is pulled round, but on the return movement of the dial the spring tightens on the spindle and forms an effective clutch between the spindle and the governor wheel 23.

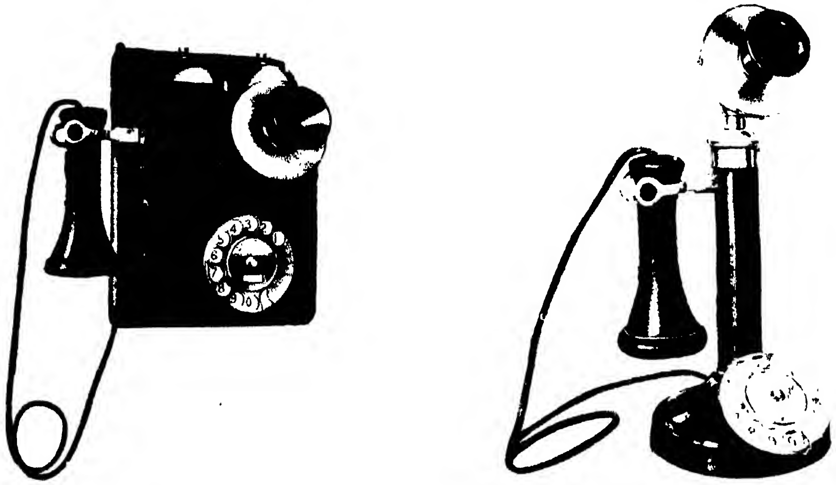
In the modification according to C and D the pawl 7 does not engage directly with the cam wheel 6, but by means of a projection 26 carried by the pawl.

Fig. 16 shows how a dial may be arranged with figures and letters in the finger holes so that a number may be prefixed by a letter. (See also Fig. 139.)

Section 8

TELEPHONE INSTRUMENTS IN AUTOMATIC SYSTEMS

Fig. 17 shows a common design of wall instrument, and Fig. 18 a typical design of a table or desk instrument. Any of the well known *common battery* circuits may be used with



FIGS. 17, 18.—WALL AND TABLE INSTRUMENT (SIEMENS).

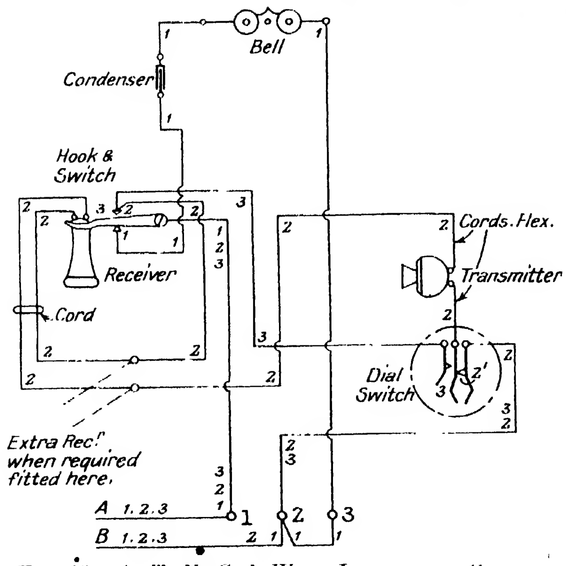


FIG. 19.—A. T. M. CO.'S WALL INSTRUMENT CIRCUIT.

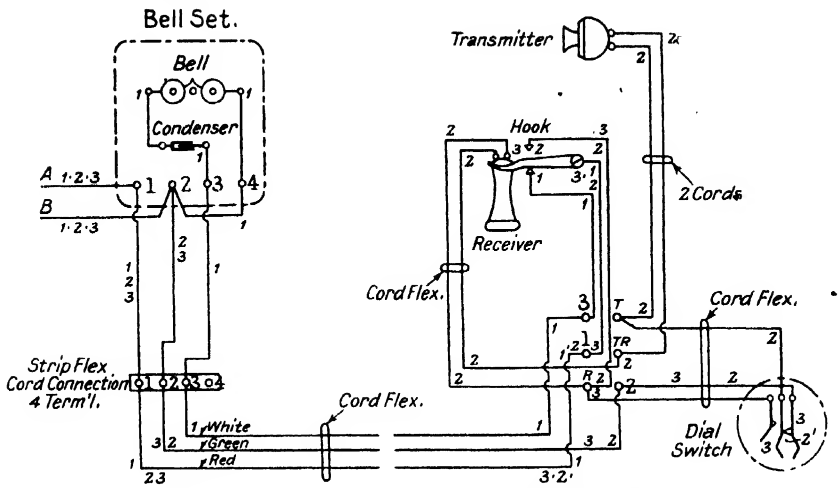


FIG. 20. A. T. M. CO.'S TABLE INSTRUMENT CIRCUIT.

these instruments, the dial impulse springs opening and closing the microphone circuit, and the receiver being short circuited by shunting springs operated when the dial is rotated.

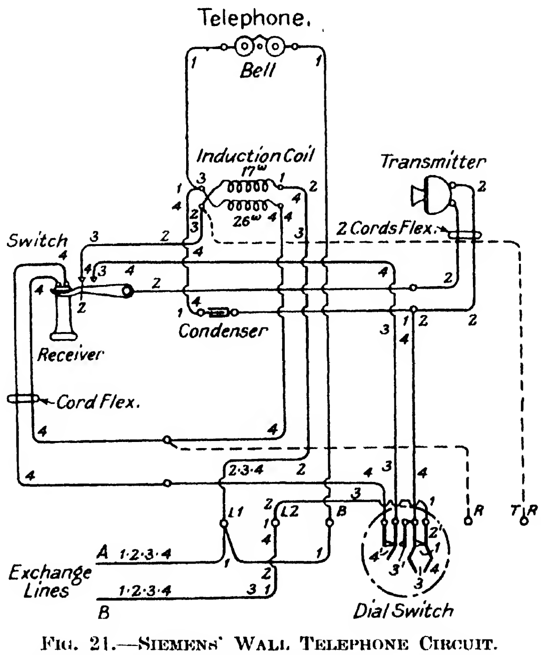


FIG. 21.—SIEMENS' WALL TELEPHONE CIRCUIT.

NOTE.—Modifications necessary for 2-party line working, unlimited rate:
X-party—Disconnect strap between terminal L1 and B, and earth B.
Y-party—As above, and join A wire to L2 and B wire to L1.

Fig. 19 shows an Automatic Telephone Manufacturing Co.'s circuit for a wall instrument and Fig. 20 the same circuit applied to a table instrument.

The instrument has no induction coil and an electromagnetic receiver is fitted in series with the microphone. This forms a very simple arrangement and is highly efficient. The turns and self-induction of the receiver have been very carefully calculated.

The circuits are numbered as follows :—

1. Bell in series with condenser for receiving incoming ringing current.
2. Receiver lifted to initiate a call. Receiver and microphone in series through dial impulse springs. This is the impulsing and also the speaking circuit. The dial springs 2′ are opened a number of times, corresponding to the value of the digit called.
3. Circuit to line when impulses are being sent, receiver and microphone are short circuited.

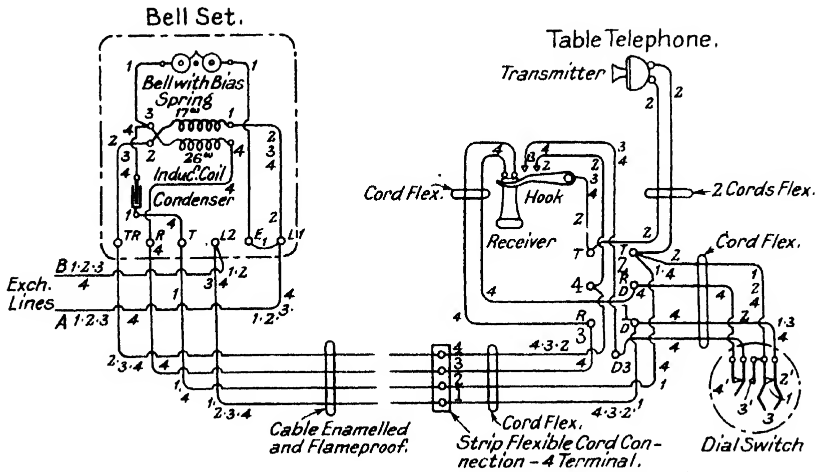


FIG. 22.– SIEMENS' TABLE INSTRUMENT CIRCUIT.

NOTE. Modifications necessary for 2 party line working, unlimited rate :
X-party—On bell set No. 1, disconnect strap between terminal E and L1, and earth E.
Y-party—On bell set No. 1, disconnect strap between terminal E and L1, earth E, join A wire to L2 and B wire to L1.

Fig. 21 shows a Siemens' circuit for a wall telephone, and Fig. 22 the same circuit applied to a table instrument. This has an induction coil with the receiver and secondary winding of the induction arranged as a shunt about the microphone.

The circuits are as follows :—

1. Bell in series with condenser for receiving incoming ringing current.
2. Receiver lifted to initiate a call. Microphone and 17-ohm winding of induction coil in series through the impulse springs 2′. This is the impulse circuit and also the speech transmitting circuit.
3. Circuit to line when impulses are being sent. Receiver circuit open at 4′, microphone short circuited at 3′.
4. Speech receiving circuit.

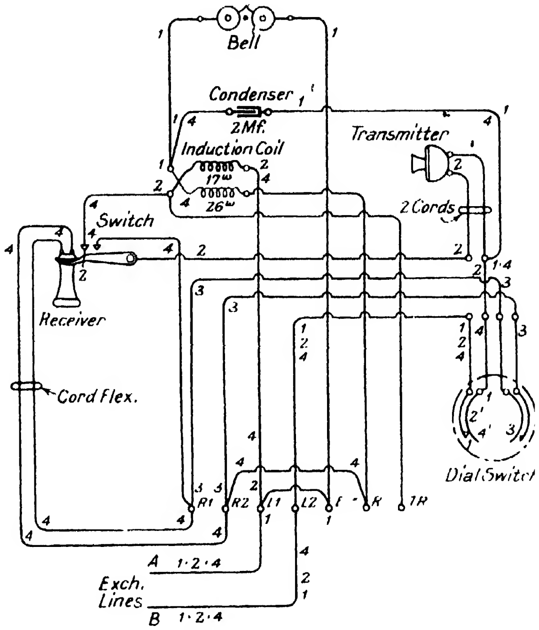


FIG. 23.—W. E. CO.'S WALL TELEPHONE CIRCUIT.

NOTE.—Modifications necessary for 2-party line working, unlimited rate:
X-party—Disconnect strap between terminal L1 and E, earth terminal E, join A wire to terminal L2 and B wire to L1.
Y-party—Disconnect strap between terminal L1 and E and earth terminal E.

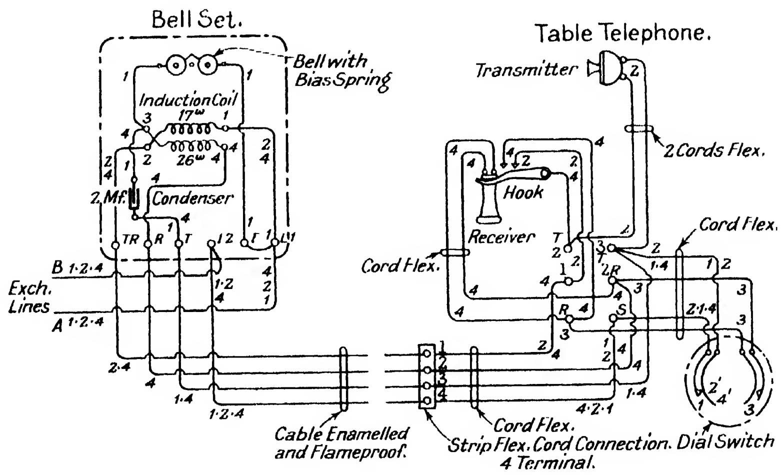


FIG. 24.—W. E. CO.'S TABLE INSTRUMENT CIRCUIT.

NOTE.—Modifications necessary for 2-party line working, unlimited rate:
X-party—On bell set No. 1, disconnect strap between terminal E and L1, earth terminal E, join A wire to terminal L2 and B wire to L1.
Y-party—On bell set No. 1, disconnect strap between terminal E and L1 and earth terminal E.

Fig. 23 shows a Western Electric Co.'s circuit for a wall telephone, and Fig. 24 shows the same circuit applied to a table instrument. These and the Siemens' circuits are practically similar, and the description of circuits 1, 2 and 4 apply.

3. Short circuit across receiver terminals whilst impulses are being sent.

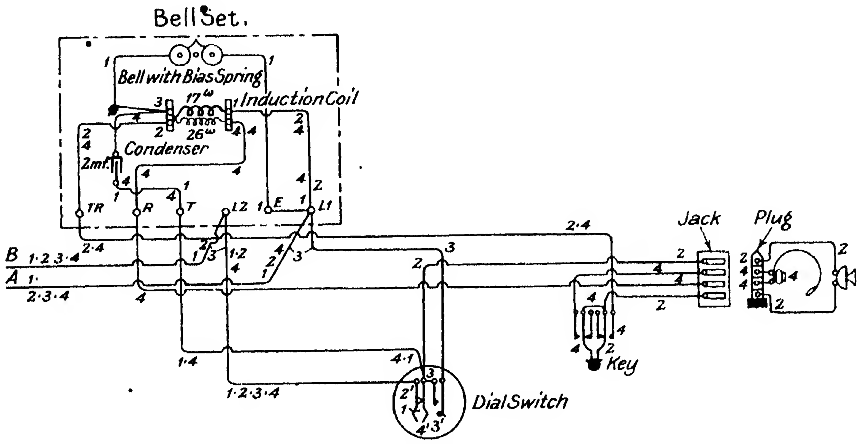


FIG. 25.—TELEPHONE COMPRISING BREAST TRANSMITTER AND HEAD RECEIVER ON A DIRECT LINE.

Fig. 25 shows a direct exchange circuit fitted with breastplate transmitter and head-gear receiver. The description of circuits 1, 2, 3 and 4 Siemens' apply.

THE STROWGER SYSTEM

The Fundamental Switch is a Vertical and Rotary Stepping Switch for 100 lines, with 10 levels and terminals for 10 lines in each level. The calling is on a decimal basis.

THE FOLLOWING FIRMS USE A SYSTEM BASED ON THE ABOVE:

AUTOMATIC ELECTRIC CO., CHICAGO, U.S.A.

AUTOMATIC TELEPHONE MANUFACTURING CO., LTD., LIVERPOOL

SIEMENS BROTHERS & CO., LTD., WOOLWICH

SIEMENS AND HALSKE, BERLIN

COMPAGNIE FRANÇAISE THOMSON-HOUSTON, PARIS

NORTH ELECTRIC MANUFACTURING CO., U.S.A.

COVENTRY AUTOMATIC TELEPHONES, LTD., LONDON

Section 9

THE AUTOMATIC TELEPHONE MANUFACTURING COMPANY'S SYSTEM

(*which embodies the system of the Automatic Electric Co., Chicago, the well known Strowger system*).

SWITCHING APPARATUS

Switches having both vertical and rotary movement are the outstanding feature of this system, operating on the decimal principle of calling.

The *selector* and *connector* are practically similar switches, the former automatically selecting an idle line in a group after the shaft is lifted to a particular level in response to the impulses of a digit, the latter responding to two digits and moving in the rotary direction step by step a distance according to the value of the final digit.

This design of apparatus has proved most reliable in action and simple to maintain. An installation fitted in Grand Rapids, U.S.A., about 1902 is still in operation and giving every satisfaction. The old plant is working on the 3-wire system, whilst the later extensions are on the 2-wire, which proves the flexibility and adaptability of automatic apparatus. It would appear also that the life of automatic apparatus can be taken at about 25 years.

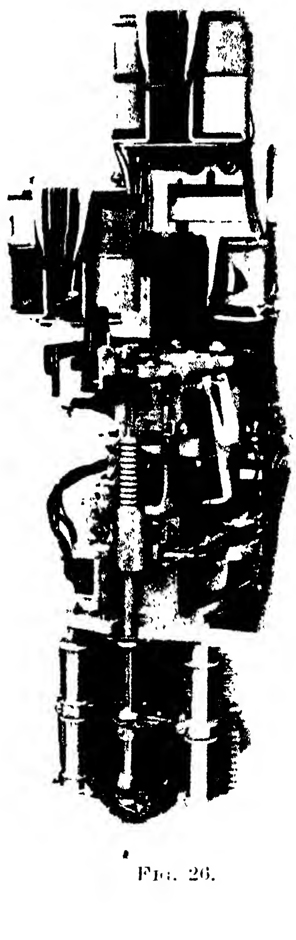


FIG. 26.

The Connector or Final Switch.—Fig. 26 shows a design only lately discarded with the relays assembled on the same mounting as the stepping mechanism. Three banks were sometimes used, the two lower ones being the line terminals, and the upper one the private or test terminals. In another design the whole of the line terminals were assembled in one bank and the test terminals in a bank above, as shown in figures 26 and 27.

REL. L. Release Line.
V.L. Vertical Line.
R.L. Rotary Line.
V.R. Vertical Relay.
R.R. Rotary Relay.
A. Shaft.
H. Hub.
P_1. Pawl.
P_2. Pawl.
V.A. Vertical Armature.
R.A. Rotary Armature.
V. Vertical Magnet.
R. Rotary Magnet.
T^1. Upper Tooth.
T^2. Lower Tooth.
D.D. Double Dog.
F.D. Fixed Dog.
P.W. Private Wipers.
V.W. Vertical Wiper.
R.W. Rotary Wiper.
a b c d Knife Switches.
S.A. Spider Arm.
B. Pivot.
C. Spring.
F. Finger.
E.S. Escapement Springs.
P.A Private Armature.
P.M. Private Magnet.
X. Stop.
Y.A. Armature.
Y_1. Coil.
Y_2. Coil.
G.R. Ringer Relay.
Z.A. Armature.
Z_1. Coil.
Z_2. Coil.
C_1. Condenser.
D_1. Condenser.
D.F. Finger.
REL. M. Release Magnet
C.S. Coiled Spring.
S.F. Finger Stop.
N.P. Normal Post.
S.A. Arm Side Switch.
S.L. Link ,, ,,
S.A.L. Lever Side Switch Arm.
V.A.F. Finger. Vertical Arm.
O.N. Off Normal.

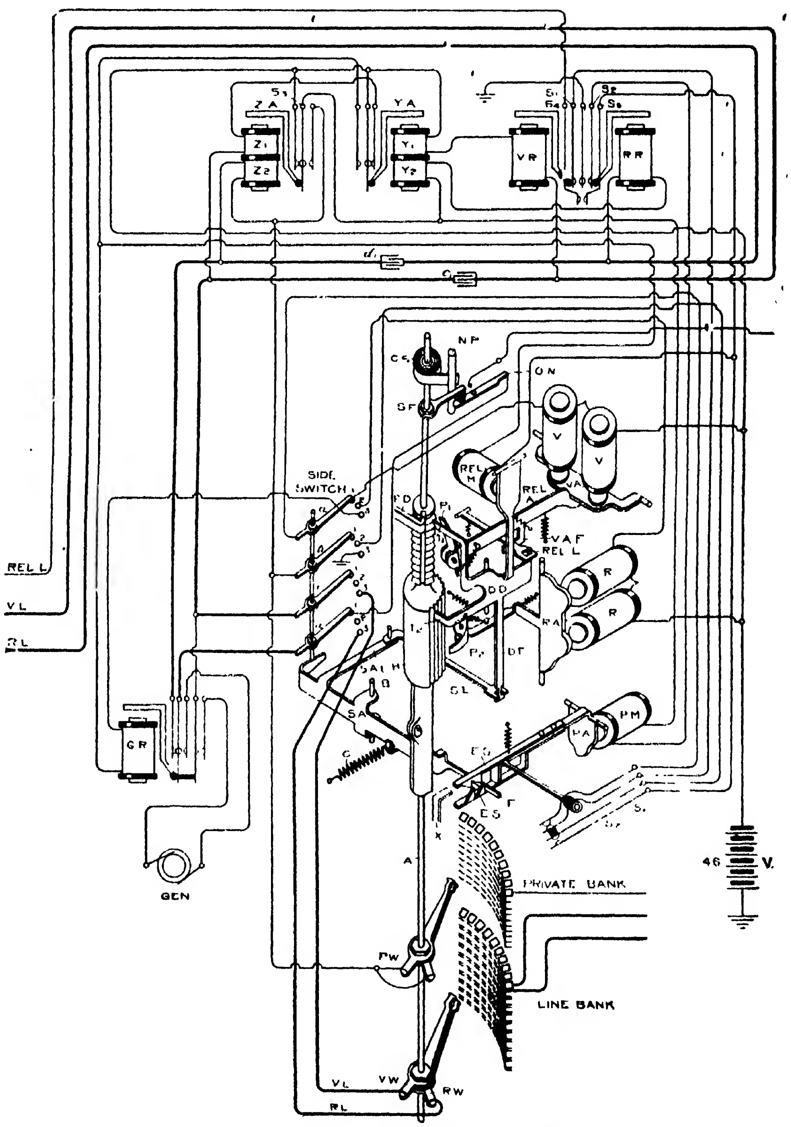


FIG. 27.—CONNECTOR WITH ITS CIRCUITS. THREE-WIRE SYSTEM.

Fig. 27 is a perspective drawing and shows the relationship of the several parts better than any photograph or geometrical drawing can. The circuit is a three-wire one and may be ignored ; the mechanical features and operating principles, however, remain practically unaltered. The names of the different parts are given in schedule form alongside with reference to the symbols of the illustration.

On a frame of non-magnetic material a vertical shaft is mounted, free to lift upward and revolve. The upper part of the shaft has teeth cut round it, and below this are other teeth in the line of the shaft, 10 teeth in each case. The shaft is raised and rotated by electromagnets. One, called the vertical magnet, acts on the teeth surrounding the shaft, and lifts the shaft to a height corresponding to the number of impulses sent, and the number of impulses depends on the second last figure of the number required, *e.g.*, if the number were 67 then the shaft would be raised to the height of six teeth. Another magnet would then be switched into action and it would act on the teeth in the line of the shaft and rotate it, the distance depending again on the number of impulses sent : in the case of the number 67 the shaft would be rotated a distance of seven teeth. The shaft at the bottom has attached to it, and insulated from it, and from each other, contact springs or wipers, which, brush fashion, wipe over contacts associated with the lines to be called. These banks of contacts (for detail *see* Fig. 28), are arranged in an arc of a circle and each line bank has 10 pairs of contacts in the height, usually in two groups, and 10 contacts horizontally in the arc, wiped over by two twin contact arms. In these contacts are terminated 100 lines. A second bank is placed above this, having 10 contacts in the height and 10 in the arc. These are connected to the test or line-engaging circuit, which is purely local and corresponds to the wire connecting the jack bushes together in a manual exchange. As the shaft rises vertically, step by step, the wipers come to rest in line with the contact levels, so that when the shaft is then rotated the wipers brush over the intervening contacts in the arc, until the wipers come to rest on the contacts of the line required. When the receiver is replaced after a conversation the circuit is opened, allowing a release magnet to operate on the "dogs" (which maintained the shaft in the position brought about by the electromagnets already described), when the shaft is rotated in the reverse direction by a coiled spring until it is free to fall by gravity to the normal position.

FIG. 28.—A SECTION OF A SINGLE BANK.

These magnets are in local circuits and are controlled by the line, or impulse, relay. An important adjunct of the early form of connector (many of which are still in use) is the side-switch, which is controlled by the private magnet. This is a four-lever three-position switch.

The connectors are arranged at the rear of a Keith line switch unit, which is shown in Fig. 33.

Fig. 29 shows how the terminals are arranged and numbered. It is to be noted that the first 10 numbers of a group of 100 occupy the top level of the bank, the second the bottom level, and the remainder follow in regular sequence upwards. The 0 of each set of 10 numbers is at the right instead of being on the left as in numerical sequence.

The Selector.—For exchanges having over 100 lines a *selector* is fitted in addition to

the *connector*. This, electromechanically, is very similar to the connector, but rather simpler, as there are fewer relays, and after it has performed its work it joins the lines through, and

01	02	03	04	05	06	07	08	09	00
91	92	93	94	95	96	97	98	99	90
81	82	83	84	85	86	87	88	89	80
71	72	73	74	75	76	77	78	79	70
61	62	63	64	65	66	67	68	69	60
51	52	53	54	55	56	57	58	59	50
41	42	43	44	45	46	47	48	49	40
31	32	33	34	35	36	37	38	39	30
21	22	23	24	25	26	27	28	29	20
11	12	13	14	15	16	17	18	19	10

FIG. 29.—NUMBERING OF CONNECTOR BANK TERMINALS.

leaves no electromagnets attached. In its operation it differs from the connector in that, after the shaft has been raised due to impulses from the dial, it rotates automatically until a junction line is found to a disengaged connector.

Section 10

A FOUR-DIGIT SYSTEM USING SELECTORS AND CONNECTORS WITH SIDE SWITCHES

In Fig. 30 is shown a four-digit Strowger circuit. In this a separate line relay is used, and a slow release relay at the connector to join up the wipers *after* the cut-off relay has disconnected the line relay of the called station, to prevent the latter being actuated by the ringing current.

In this circuit either subscriber can clear the connection.

The circuits are numbered in the order of operation as follows:—

1. Circuit in which the line relay L operates when the receiver is lifted.
2. The line switch LS operates to pull down both armatures, when the plunger operates the group of springs. L de-energises.

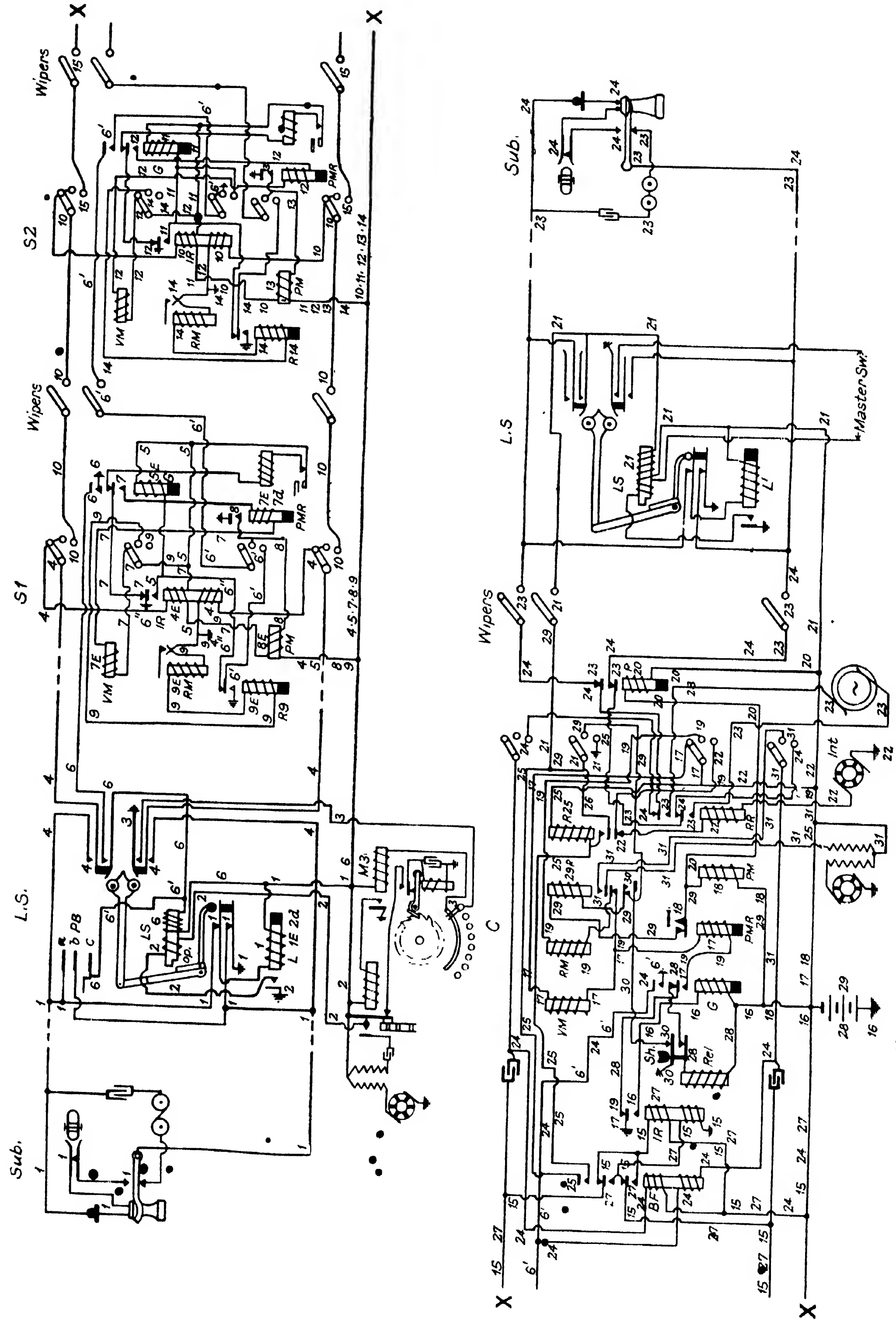


FIG. 30.—STROWGER 4-DIGIT CIRCUIT WITH SIDE-SWITCH SELECTORS AND CONNECTORS.

3. Master switch operated to move the plungers opposite the next idle trunk.

4. Loop 1 extended to relay IR.

5. Guarding relay G energises.

6. Holding circuit of LS guarding earth on private bank PB. Subscriber pulls dial for first digit. IR de-energises according to number of times the circuit is broken.

7. Vertical magnet VM operates to lift shaft to the level corresponding to the digit. PM energised for duration of impulses.

8. Private magnet PM energises. PMR and PM de-energise after impulses, and latter moves the side-switches SS to second position.

9. Side switch completes circuit to rotary magnet RM and R3. RM when energised opens its circuit (trembler bell fashion) so that the wipers are stepped round until an idle line is found. The armature of PM is pressed down for each step. If line is busy, PM remains down, and wipers again move until a terminal with no guarding earth is found, when PM armature falls back and causes side switches to move to third position.

10. Loop 1 and 4 extended to second selector.

11. Guarding relay G energised.

6′, 6″. Guarding and holding circuit. Subscriber pulls dial for second digit. IR de-energises.

12. Vertical magnet steps up wipers. PMR energised.

13. PM energised during impulses; on de-energising moves side switches to second position.

14. Rotary magnet energised, intermittently, to move wipers round to idle line. PM de-energising moves SS to third position.

15. Loop 1, 4, and 10 extended to connector relay IR.

16. Guarding and holding relay circuit.

6′. Guarding or third conductor circuit. Subscriber pulls dial for third digit. IR de-energises.

17. Vertical magnet VM lifts shaft.

18. PM circuit. PMR and PM de-energising move SS to second position. Subscriber pulls dial for fourth digit. IR de-energises.

19. Rotary magnet RM, controlled by IR, moves wipers step by step to contact required.

20. R20 was energised, in parallel with PM, to open circuits to wipers, whilst passing over level contacts, and de-energises with PM.

21. Line switch LS energised to pull down inner armature only, to cause cut-off springs to disconnect line relay L.

22. Ringing relay RR energises intermittently (by int.).

23. Circuit of ringing current to subscriber's bell. Relay R20 is made slow to release, thus giving time for LS to cut-off line relay L′ before ringing current is applied to line.

24. Receiver lifted and battery-feed relay BF energised.

25. R25 energises to cut off ringing relay RR.

26. Locking circuit of R25 to prevent ringing current being reconnected.

27. Current reversed, to calling subscriber, to meter, etc. When receiver replaced to clear, IR de-energises and opens circuit 16. G de-energises.

28. Circuit of release magnet Rel., which restores connector shaft to normal, and breaks normal contacts and circuit 28. G also opens circuit 6 to release selectors, and opens

24 to de-energise BF, which restores normal battery to calling line side, although calling receiver may not be replaced. If caller replaces receiver first, IR de energises.

If the called line had been busy, the side switches would have remained in the second position.

29. Testing circuit in which R29 energises (this circuit closed when PMR de energises after last impulse), PM energises, and side-switches SS are not moved to third position.

30. Locking circuit of R29 and PM opened when shaft falls.

31. Tone test circuit to calling subscriber. Receivers replaced, circuit opened as before.

Section 11

THE LINE SWITCH

A *Keith line switch* (Figs. 31, 32) is introduced between a subscriber's line and a selector. This is to avoid the necessity for having an expensive selector associated with each line. Each line has its line and cut-off relay (plunger magnet) like the manual exchange. These are arranged on each side of a vertical moving shaft in groups of 25, 12 on one

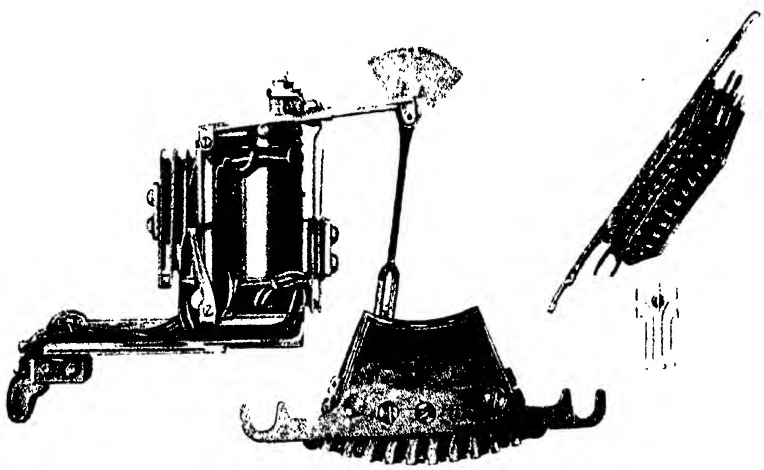


FIG. 31—KEITH LINE SWITCH, SHOWING PLUNGER AND BANK CONTACTS

side and 13 on the other. This shaft is pivoted and has a backward and forward movement. Each relay has a pivoted arm or plunger whose fan-shaped end has a notch which engages with the moving shaft normally. As the shaft moves it carries with it the plungers and causes them to move on their pivots, so that the point which carries ebonite rollers is moving in front of sets of springs. One bank or level of 10 groups of springs (Fig. 31) is in line with

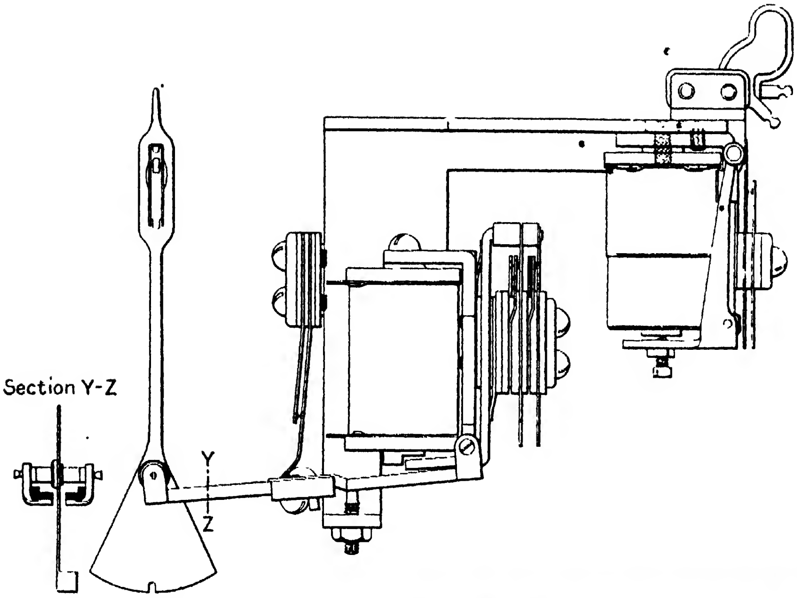


FIG. 32. KEITH LINE SWITCH. PRESENT FORM. EQUIPMENT OF ONE SUBSCRIBER'S LINE.

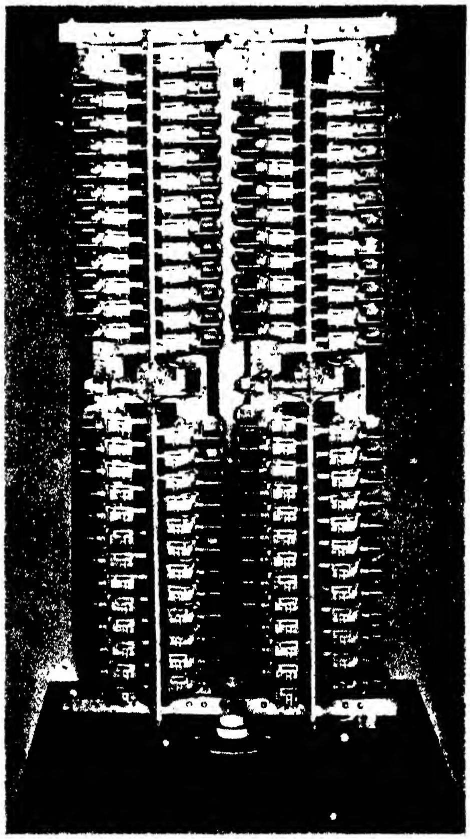


FIG. 33.—KEITH LINE SWITCH 100-LINE UNIT

The meters are sometimes placed above, but are preferably fitted apart for convenience in reading.

The unit is fitted in an enclosed cabinet with glass doors. The necessary terminal straps are at the top.

The associated connectors are fitted at the rear.

each plunger. The corresponding groups of springs in a unit are multipled together and connected to a selector. The unit is usually made up of four sections of 25, with which 10 selectors are associated, and the shaft is rocked by a master electromagnet. When the telephone is removed, and before the dial has sent out impulses, the line switch is operated automatically; the operating relay has disengaged the plunger from the shaft and driven it into a group of springs, so that the subscriber's line has been extended to a selector; at the same time local circuits have been completed through the cut-off relay and the master switch electromagnet, so that the shaft is moved one step, and the remaining 99 line relay plungers are opposite the No. 2 selector set of springs. The next call will engage No. 2, and the remaining 98 will then be carried opposite No. 3, a selector being thus always pre-selected. As the plungers become free, the shaft picks them up on its return journey, or they are made self-aligning so that they return to the shaft.

Circuits of this line switch are shown in Fig. 43, in connection with which the action is more fully explained. Fig. 33 shows a unit of 100 lines of these switches.

Section 12

MASTER-SWITCH WITH POWER SOLENOID (Fig. 34)

This is fitted centrally in a panel and controls 100-line switches, but usually a spare master-switch is provided, so that either can control 100 lines, or each control 50 lines.

In Fig 34 *e* designates the master-switch shaft which is linked with the line-switch shaft *f* to give the latter a to and-fro or oscillating motion.

The travel control notched cam *b*, the speed-governing geared segment *g*, the spring release and circuit-closing arms *d* and *c*, are rigidly fixed to the shaft *e*. The shaft is rotated in a clockwise direction by the part *h*, which is connected with the plunger of the solenoid *s*, and rotated anti-clockwise by the C-spring *j* forcing apart the stud *k* fixed to the plunger, and the part *h*. The armature of the relay R2 carries a locking dog *a*, which normally engages with the notches to lock the cam in position, but when the relay is energised, the dog is lifted and the cam is free to move in either direction. The notches of the cam correspond in number with the bank contacts, so that the dog in a given notch means that all the line-switch plungers have been moved opposite a given trunk (having 100 multipled points). The trunk line is pre-selected, and when, *e.g.*, No. 5 trunk is engaged, the dog is lifted and the cam moves counter-clockwise until the next idle line is found, when the dog re-engages. When the last notch is passed, the arm *c* closes the two springs *l*, *m*, to energise relay R3 and the solenoid *s*. The relay contacts *n* are held closed by the latching spring *o* until the solenoid *s* has pulled in its armature and plunger. The arm *d* then comes against the latching spring *o* and allows the relay springs *n* to return to normal, when the solenoid is de-energised. The rate of travel is controlled by a governor *p*, similar, but of heavier pattern, to that described for the impulse dial.

Each master switch has a series of contacts corresponding to the number of trunks controlled, in this case 10, with a contact arc over which an insulated wiper rubs to connect the arc with each trunk in turn.

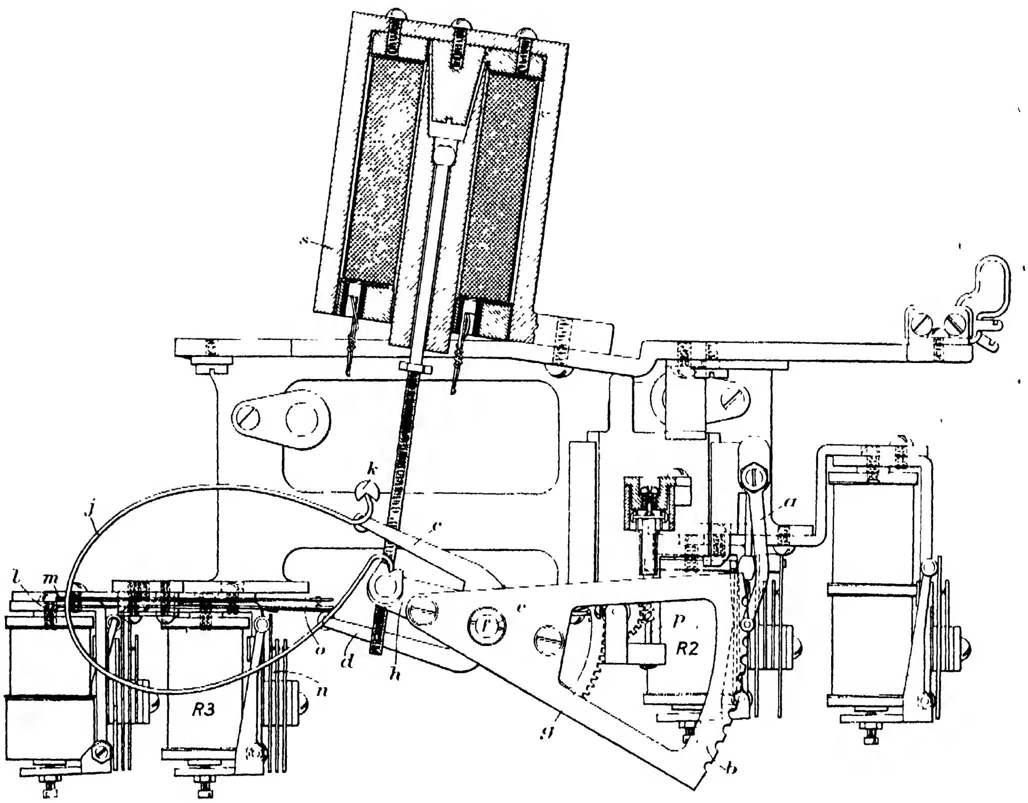


FIG. 34.—MASTER-SWITCH OF "KEITH" LINE SWITCH.

As an idle trunk is preselected, there is no testing or hunting, and the plunger of the calling line enters the bank contacts instantly.

The circuits of the master switch are shown in Fig. 43.

Section 13

THE AUTOMATIC TELEPHONE MANUFACTURING CO.'S LATEST SYSTEM

The Connector (Fig. 35).—At A, B, C, D, are shown four views of the new type *connector* switch. The relays are now fitted apart from the switch frame or mounting, on a base plate, which also carries the switch frame. The relays are fitted horizontally above the switch, and wired from the rear. The switch frame is now of cast iron, very heavily zinc-plated, and is found to be more rigid than the die-casting. This frame carries the vertical,

rotary and release magnets, and the shaft dogs, pawls and other accessories. The banks are fitted below, and, with the wipers, which are fixed to the shaft, are not shown in the illustrations.

Side switches are not now used relays taking their place.

The relay has been redesigned; the point pivot has been replaced by a pin pivot which

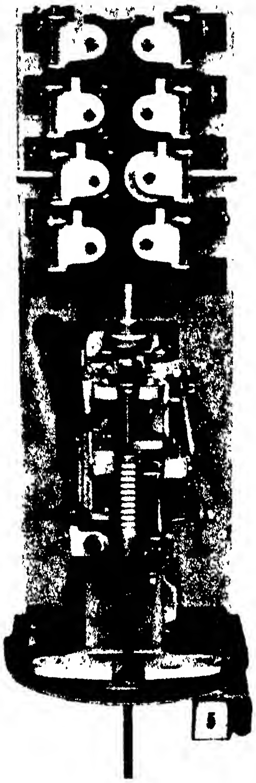


FIG. 35A.—FRONT VIEW. A. T. M. CO.'S LATEST PATTERN CONNECTOR.

FIG. 35B. A. T. M. CO.'S CONNECTOR. FRONT VIEW WITH COVER.

does not require adjustment: phenol-fibre is now used for insulating the springs, and each spring unit is aged by a heat treatment.

The switch is adjusted to work efficiently with a loop resistance of 1,000 ohms, which still allows an ample margin of safety.

On referring to the illustrations, it will be seen that the mechanically operating parts are very similar to the older switch (Fig. 27). The off normal contacts are seen on the left-hand side of the front view, and are operated through a lever by the head of the shaft.

The switch and relays are closed in by a cover, which, however, leaves the banks and wipers exposed.

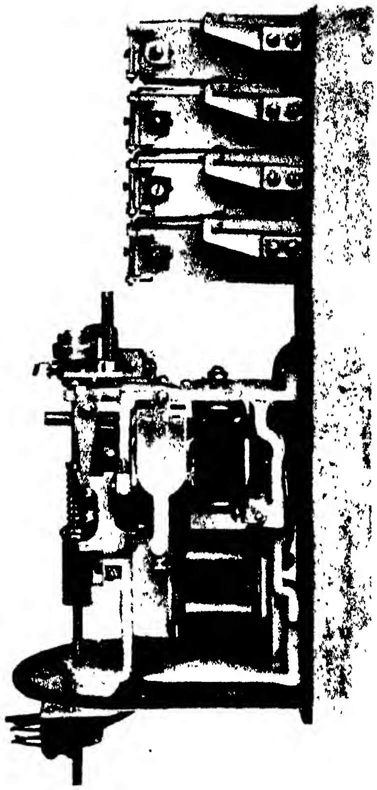


FIG. 35C.—VIEW OF RIGHT SIDE OF A. T. M. CO.'S LATEST CONNECTOR.

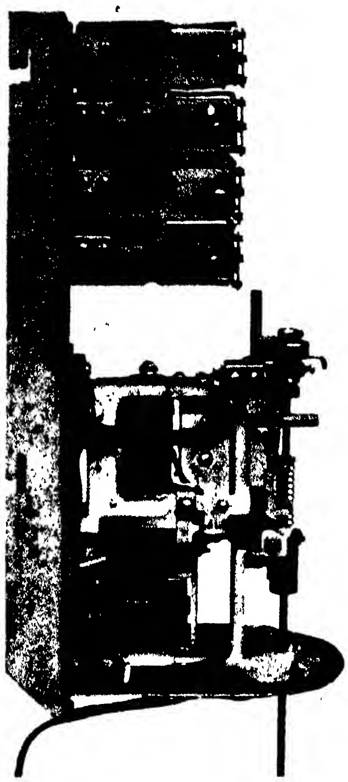


FIG. 35D. VIEW OF LEFT SIDE OF A. T. M. CO.'S LATEST CONNECTOR.

The *selector* switch is similar in appearance.

COPPER-CLAD RELAYS are extensively used. When a mass of copper is fitted over the core at the "heel," or fixing end, the relay is made slow to de-energise; when fixed at the armature end of the core, it is slow to energise and de-energise.

Section 14

NEW LINE SWITCH IN A. T. M. CO. SYSTEM

The Rotary Line Switch (Fig. 36, *a*, *b*, *c*, *d*, *e*).—This is a new feature in this system, and was first used in the Orleans exchange, France. It is the first self-propelled rotary switch to be used in important exchanges. The wipers rotate at 60 to 80 steps per second. There are 25 sets of terminals in the arc, which number gives each calling line access to a

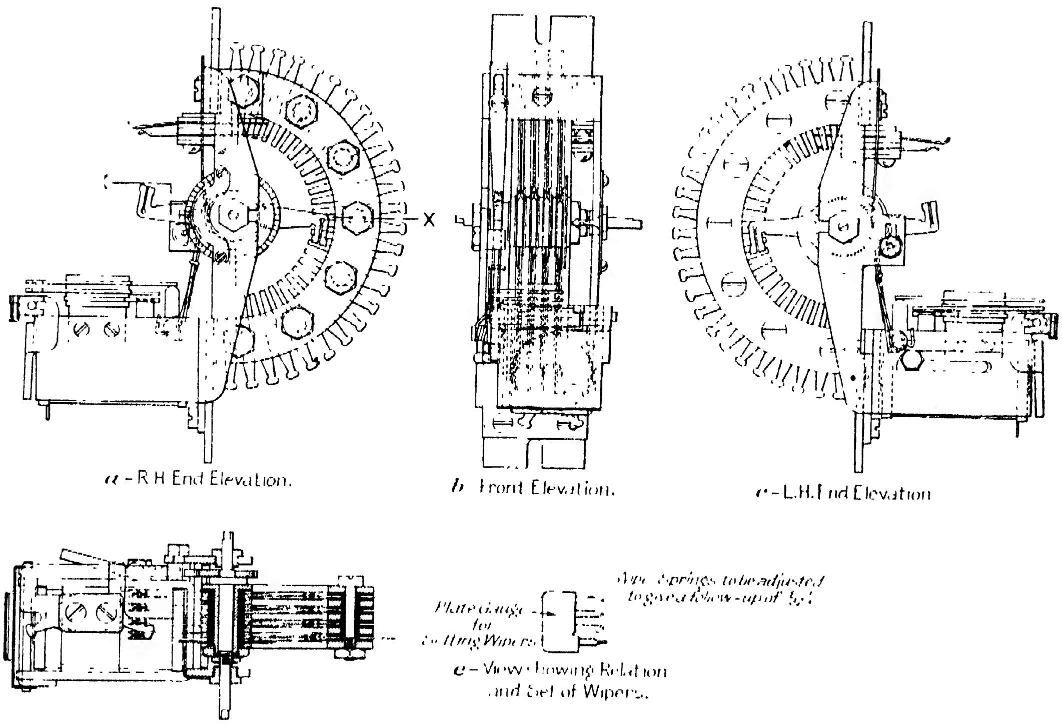


FIG. 36. A. T. M. CO.'S SELF-PROPELLED ROTARY LINE SWITCH FOR 25 TRUNKS.

large group of outgoing trunks. The lifting of the receiver to make a call starts the switch hunting for an idle line, a switch being associated with each subscriber's line. It has no normal position to return to, but the wipers remain in position on the trunk last used. The wipers being then insulated, this has no harmful effect. When another call is made, the switch immediately makes connection with the terminals and trunk on which it rests, but if that is busy, it instantly moves to find an idle line.

The switches are arranged vertically as shown in Fig. 37, which represents a 100-line private automatic exchange (P.A.X.), the connectors for incoming calls being fitted in the rear.

A driving magnet only is required in addition to the line and cut-off relays. The motor magnet armature has a pawl which normally locks the wipers on any trunk. When energised, the magnet withdraws the pawl so that it catches the next tooth on the ratchet wheel. When de-energised, the armature spring drives the pawl and rotates the wipers to the next

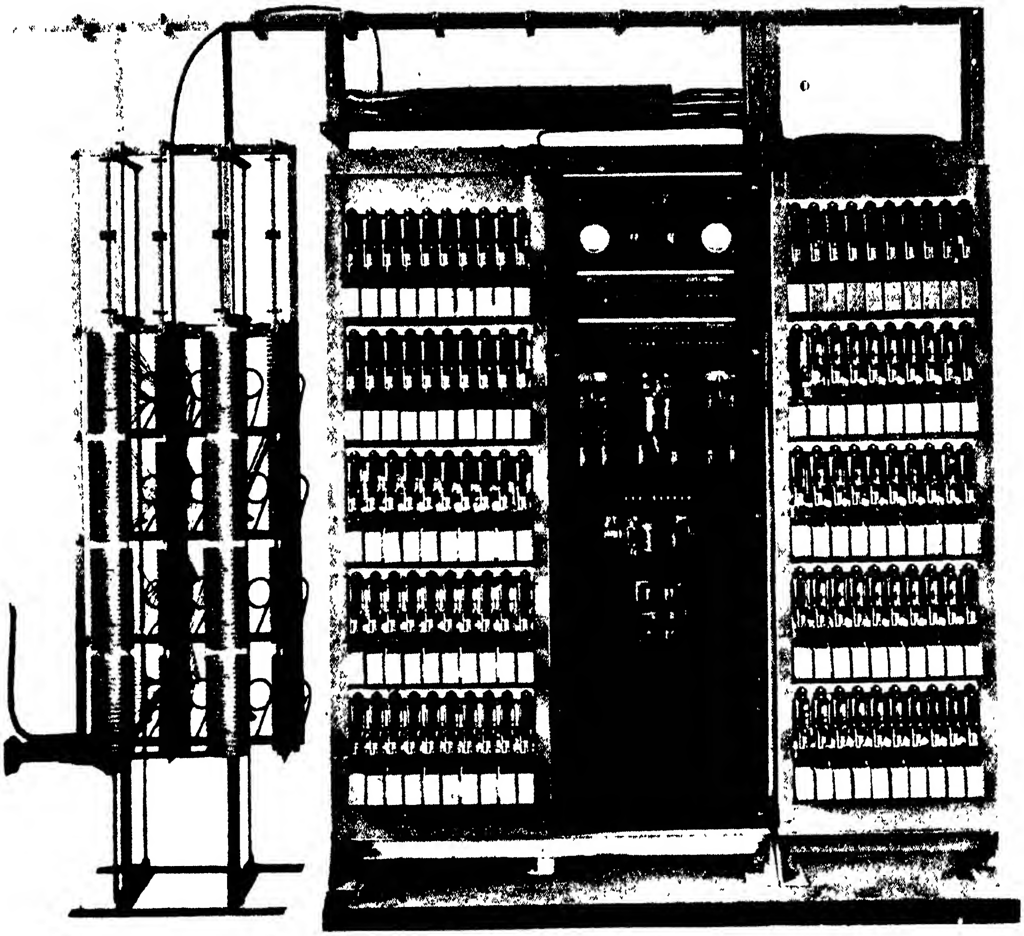


Fig. 37. 100-Line Private Automatic Exchange (P.A.X.), showing Rotary Line Switches.

set of terminals and locks them there. The wipers are of special design with split tongues to give flexibility and good contact. There are two sets of wipers in the same straight line, so that all the terminals are made contact with in half a revolution, the second set of wipers coming into action when the first leaves the arc.

The drawing shows four sets of wipers and levels, but only three are used on the circuit, Fig. 39.

The line and cut-off relays are so related that they interlock. If the line relay is de-energised, as on an incoming call, the cut-off relay cannot pull up fully, but only sufficiently to cause the line relay to break from its back contacts, but not sufficiently to make with its front contacts. This is brought about by a mechanical device. When the line relay is first energised, as for an outgoing call, the armature pulls up fully, and makes with contacts to connect the calling line through to the wipers. The switch is held energised in the third

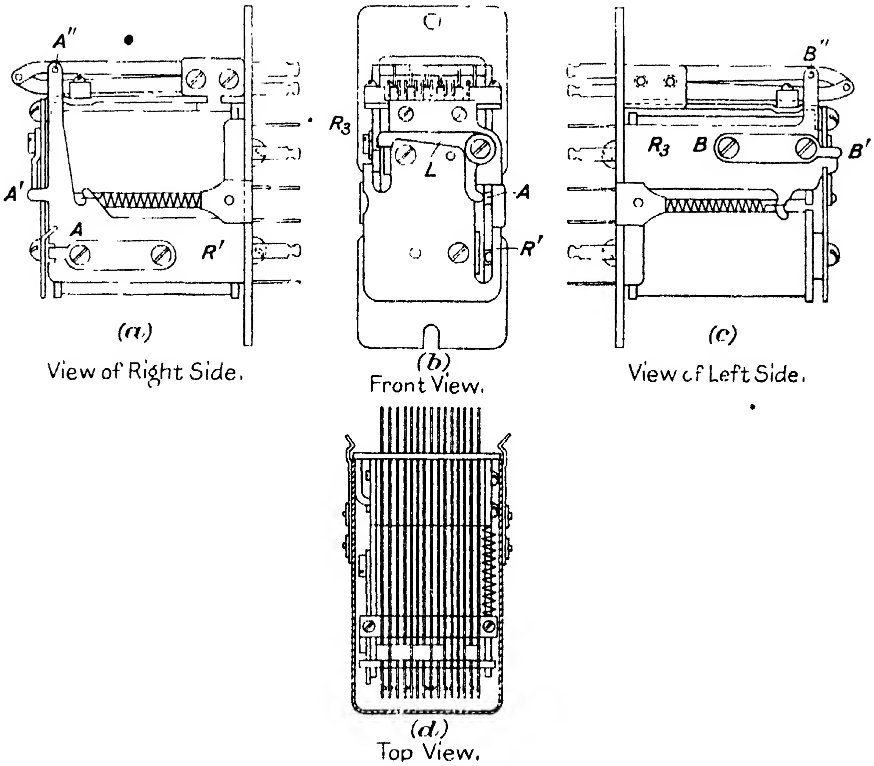


FIG. 38.—LINE AND CUT-OFF RELAY FOR A. T. M. CO.'S ROTARY SWITCH.

conductor circuit, and a clean line circuit established. This special line and cut off relay is shown in Fig. 38, *a*, *b*, *c*, and *d*.

The lever L in the normal position prevents the armature B by the lug B', of relay R3 from pulling up fully. If, however, R' is first energised, the armature lug A' of relay R' displaces the lever L, so that the R3 armature may now pull up fully and make with inner contacts.

All the contact springs are arranged on the top of the upper relay as shown in Fig. 38 *d*. The armature A of relay R' has an extension A'' which carries a rod, having suitable insulations, to operate a series of spring contacts. The armature B of relay R3 has a similar extension to operate another set of contacts.

Section 15

CIRCUITS OF A 1,000-LINE EXCHANGE, A. T. M. CO. SYSTEM

Rotary Line Switch Circuit (Fig. 39).—This switch has no normal position, but remains on the set of terminals with which it last made connection. The line on which the wipers rest may be used at another position. When a call is made, the switch will immediately connect with the line occupied if it is idle, but will step to an idle line if it is busy.

As used on outgoing calls :-

1. When the receiver is lifted, R′ (B), slow to de-energise, energises.

2. If the line on which the switch is at rest is busy, R′ (B) shunts the relay R3 (A), to prevent it from operating. The rotary magnet RM2 energises and steps the switch to the next set of terminals. RM opens circuit 2, de-energises, and again closes circuit 2, when, if the next line is also busy, it will again energise, step the switch, and break circuit 2. This will continue until an idle line is found.

3. The shunt circuit on R3 is opened, and R3 (A) energises in series with RM2. RM does not energise because of its resistance and adjustment.

4. R3(A) extends the calling line to the wipers and, *e.g.*, to the impulse relay R4 of the selector, which will energise and then close a circuit 8 to energise a relay R8.

5. The holding circuit is extended through the Pr. wiper to earth at R8. The private normal on the connector then tests busy.

6. The holding relay R3 is held energised.

Relay R′ is slow to de-energise to keep circuit 3 closed until the relays on the next switch pull up.

Release. When the receiver is replaced, R4 and R8 de-energise, and circuit 6 is opened, so that R3 de-energises and connects up R′.

Incoming calls :

7. When the line with which the switch is associated is called, the connector earths the private bank contact. R3(A) is operated just sufficiently to open circuit 1 and cut off R′. This movement is effected mechanically, relays R′ and R3 being so arranged that R3 can only pull up through its full stroke when R′ is energised.

Side-switchless Selector Circuit (Fig. 40).—When circuit 4 is extended, as above described, R4 energises.

8. R8 energises (slow to de-energise). The battery to R8 is taken through a 15-ohm supervisory relay associated with the shelf, so as to operate a lamp signal, in case the line should become short-circuited, or should the caller omit to replace the receiver.

6. R8 earths the release wire.

First digit impulses :—

9. At each de-energisation of R4, the vertical magnet VM steps up the wipers a distance of one level. R9(C) energises.

10. A $\frac{1}{2}$ microfarad condenser, in series with a 10-ohm resistance to earth, prevents excessive sparking at the impulse springs of R4.

11. Relay R11(E) energises.

12. R11 locking circuit. R14 is shunted so that it cannot energise until an idle set of terminals is found.

13. When the impulses cease, R9 de-energises (it remained energised during the impulses), and the rotary magnet RM is energised. RM steps the wipers to the first set of terminals, and if the test terminal is not earthed, due to some other switch occupying a multiple of it, opens circuit 9, so that R9 de-energises and removes the shunt from R14(D), and opens the RM circuit 13.

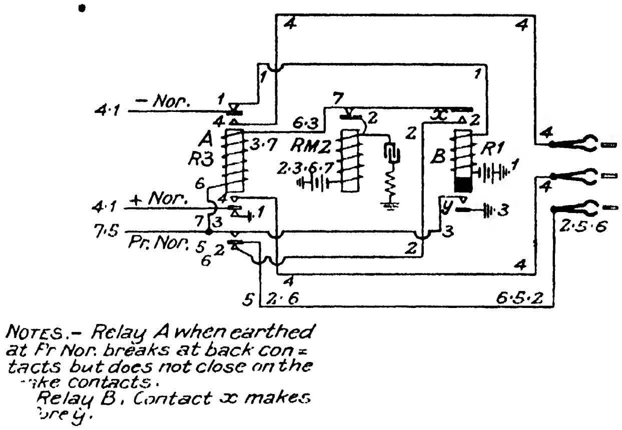
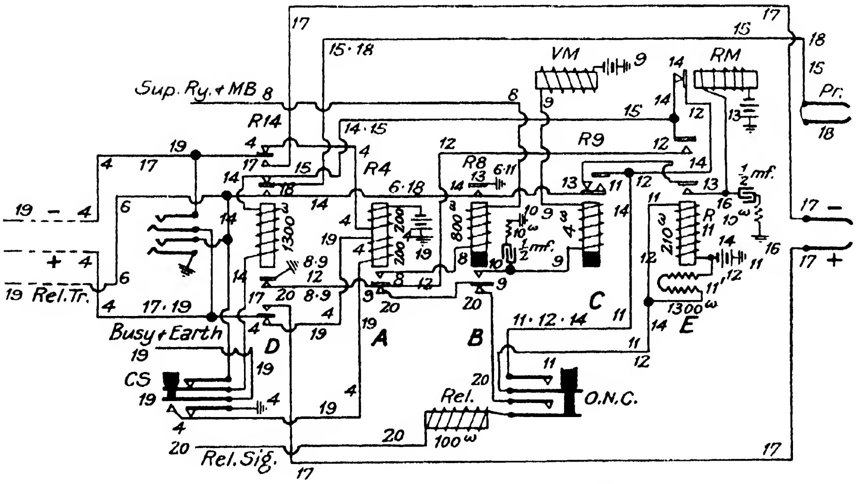


FIG. 39. A. T. M. CO.'S ROTARY LINE SWITCH CIRCUIT.



RM. Adjust contacts to break just as double dog falls in. Relay E to be adjusted so as not to hold up in series with relay D. Off normal contacts ONS close on first vertical step just before double dog falls in.

CS. These springs are switched on the eleventh rotary step by switch shaft cam.

FIG. 40.—SIDE-SWITCHLESS SELECTOR CIRCUIT.

14. The RM armature drops back, and R14 energises in series with relay R11(E), through the off-normal springs ONS. R11, on account of its resistance and stiff spring adjustment, does not operate.

15. If, however, the first test terminal is earthed (line busy), R11 on de-energising (when its circuit was opened by the RM contact) will not open the shunt to R14, as the shunt is then completed through the back contact of R14 to the private wiper Pr. When the rotary

magnet de-energises, R11 will again pull up over circuit 14—15. The rotary magnet will again operate in circuit 13 to move the wipers to the next terminals. This operation will be continued until an idle line is found, or until the wipers pass off the tenth contact. This removes the earth from the Pr. wiper, and prevents R11 from energising, thus preventing further rotation of the switch.

16. To prevent excessive sparking at the make contact of R11, a ½-microfarad condenser, in series with a 10-ohm resistance, is connected to one side of the rotary magnet.

11'. To prevent excessive sparking at the RM contact springs, which interrupt the circuit to R11, a 1 300 ohm non-inductive winding is wound on top of, and in multiple with, the 210-ohm winding of R11.

17. When an idle line is found, R14(D) energises, and the line is joined through to the next switch, which, if a connector, R' and R2 (Fig. 41) energise.

18. The release wire is connected by the Pr. wiper to circuit 3 (Fig. 41). R8, being slow to de energise, keeps R14 energised until this circuit is completed. R14 causes R4 and R8 to de-energise.

If an idle line is not found, the shaft, on the eleventh rotary step, operates the cam springs CS, which opens the circuit to R4, which de-energises and then causes R8 to de-energise. Earth is thus removed from the release circuit 6.

19. The cam springs also take direct earth off the positive winding of R4, and replace it with another earth upon which is superimposed the busy tone, thus informing the caller that all trunks are busy.

20. Release. When the caller replaces the receiver, the line circuit is opened at the connector, and earth cut off the release circuit 18, when R14 de-energises. The release magnet operates and releases the selector. When the shaft returns to normal, the release circuit is opened at the off normal springs.

A copper sleeve over the core of the 100-ohm release magnet prevents excessive sparking at the off-normal release springs.

The battery to the release magnet is taken through a relay slow to de-energise, associated with the shelf, so that if for any reason the release circuit remained closed, an alarm would be given. This release signal relay is slow-acting, so that in case the number of calls are to be registered, a meter can be operated.

Section 16

A. T. M. CO.'S SIDE-SWITCHLESS CONNECTOR CIRCUIT

Release when last party replaces the receiver (Fig. 41).

The circuits are numbered in the order of operation and are as follows :—

1. When a calling line is extended to a connector relay R'(A) energises.

2. Relay R2(B), slow to de-energise, energises.

3. Release trunk earthed. This is the holding circuit to maintain energised all the switches towards the calling line. The release circuit is also opened and the vertical magnet circuit prepared.

4. At each interruption of the circuit 1 at the calling device, R′ drops back and operates the vertical magnet VM in series with relay R4(C). The shaft and wipers are raised to the called level.

5. A ½-microfarad condenser in series with a 10-ohm resistance to earth, from the make contact of R2, prevents excessive sparking at contact of relay R′.

As soon as the shaft is stepped up one level, the off normal springs, ONS, switch the vertical circuit, at its make before break springs, from the make contact to the back contact. It also partly completes the release circuit.

4′. Relay R4(C) opens the rotary circuit 6 and closes the vertical magnet circuit 4′, through the back contact of the make before break off normal springs.

When the impulses from R′ cease relay R4(C) de-energises (being slow to de-energise, it did not release during impulsing) and switches the circuit from the vertical to the rotary magnet RM.

6. The impulses of the final digit are now received, and the rotary magnet RM steps the shaft and wipers round to the terminals of the called number.

5. The ½-microfarad condenser associated with R2 again prevents excessive sparking at contact of R′.

7. Relay R7 energises in parallel with RM. This prepares the private wiper Pr. through to R24(G), and short-circuits the back contacts of R24 at 7′ through which the rotary magnet circuit is taken, so that R24 will not open the rotary magnet circuit while the private wiper passes over busy contacts.

8. When the impulses cease relay R7(E) de-energises and, providing the private bank contact is not earthed due to being in use, energises the 125-ohm winding of R8(H) in series with the bridge cut-off coil of the called line switch from earth at R2 circuit 3.

9. Relay R8 locks itself through its 1,300-ohm winding to earth.

10. The interrupter start is earthed so as to start the ringing interrupter. It also opens the rotary circuit 6 so as to prevent further rotation of the shaft in case the calling party should again turn the dial.

11. The private wiper is earthed at R2(B), thus making the called number busy to others. This earth, over the private wiper, also earths the private normal to the called line switch, thus operating the line switch bridge-cut off relay, which cuts the bridge of the called line switch line relay from the called line.

12. Relay R8(H) also closes the line wiper circuit, thus closing the ringing circuit to the called line from earthed generator, through the make contact of the interrupter relay resistance lamp, called party's ringing lamp, and 200-ohm winding of R12(F) to battery. The back contact of the interrupter relay is connected directly to earth, and this alternates on the line with the grounded generator. The called bell is rung intermittently from battery through the 200-ohm winding and back contact of F to earthed generator. R12(F), however, being marginal, will not pull up with the ringing current in series with the ringer and condenser. Also it cannot pull up when the direct earth is put on the line.

The copper sleeve and heavy ring on the core of F gives it greater range of adjustment and also reduces the impedance of the ringing current. The ringing current also induces a current in the 1,300-ohm winding of F, which forms a circuit through the positive winding of D, positive talking condenser, calling party's talking loop and negative winding of A to battery, thus giving the caller an audible signal every time the called bell rings.

As soon as the called party answers R12(F) energises and opens the ringing circuit.

13. Locking circuit of R12.

14. The called line is connected to relay D(R14). Circuit 10, to the ringing interrupter starting relay, is opened so that the interrupter is not operated whilst the switch is in the talking position. The interrupted generator lead is opened so as not to earth the positive line to the called party.

15. The calling supervisory circuit is closed.

16. Relay D reverses the battery to the calling line so that meters or coin collectors can be operated if desired, or for supervision in connection with toll boards.

17. The calling supervisory circuit is opened.

18, 18'. Multiple circuit to the 1,300-ohm locking winding of R12(F) and R8(H) so that these cannot restore and open the circuit to the called line when the calling line releases before the called.

19. Talking circuit through the two 2-microfarad condensers.

20. When the caller replaces the receiver circuit 1 is opened. R' de-energises and opens circuit 2. Before R2 de-energises a circuit is completed to R7(E), which energises and opens circuits 8' and 8, so that when R2, on restoring, opens circuit 3, the switches held operated over the release trunk can restore.

When R2 de-energises it opens circuit 7, but as R7 is slow to de-energise it held the circuit to the release trunk open long enough to allow the switches to restore.

3, 8, 8'. When R7 de-energises it again restores the release trunk earth through R8 125-ohm winding to prevent this connector being seized until the called party clears.

Relay R2 also prepares the release circuit, but as the called party has not cleared R14(D) remains energised and prevents the closing of the release magnet circuit.

21. R2 de-energising closes the called line supervisory circuit. This supervisory is taken through a relay associated with a slow acting set, so that if the called party does not clear within a reasonable time a visual and audible alarm will be given.

22. When the called party clears relay R14(D) de-energises.

23. The release magnet energises and releases the switch. As soon as the shaft returns to normal the release circuit is opened at the off-normal springs. A 500-ohm non-inductive resistance wound on top of, and in multiple with, the release magnet prevents excessive sparking at the off-normal release springs. The battery to the release magnet is taken through a slow acting relay associated with a group of switches so that if for any reason the release magnet circuit remains closed, an alarm will be given. This release signal relay is slow acting, so that, in case the number of calls are to be registered, a meter can be operated.

17. When the called party clears first, R14 de-energises and closes the calling supervisory circuit, which, when used, is wired to a lamp associated with a slow acting set, so that, if the caller should not clear within a reasonable period, a visible and audible alarm will be given. The entire connection is maintained until the caller clears, when R' de-energising opens circuit 2 to de-energise R2, which in turn closes the release magnet circuit and allows the switch to restore to normal.

24. If the number called should be busy, earth over the private bank and wiper operates R24(G), relay R7 momentarily holding the circuit to R24 closed, after the impulses from R' cease, on account of its slow release action.

25. R25 locks itself to ground over the private wiper.

25'. As soon as R7 de-energises, after the series of rotary impulses, it switches the

locking circuit of R24 from the make to the back contact of its make-before-break springs to earth at R2.

Relay R24(G) opens the rotary magnet circuit 6 to prevent further rotation of the switch, in case the caller should again turn the dial.

26. Busy tone is connected to the positive line of the caller through the condenser, so that two or more switches calling busy numbers will not be locked up over the common busy wire. The busy tone is also taken through a condenser, common to each unit, so that, in case the busy circuit should become earthed, it will not be out of service in the entire exchange. R24 also opens circuit 8 to the private wiper so that R8 cannot operate and establish the circuit in the ringing position after the busy number called is freed.

25. R24 is locked up from earth at the make contact of R2 instead of from the private wiper, so that it will not restore when the called party clears, and close the circuit to R8 and establish the circuit in the ringing position.

The caller cannot, of course, come in on the number called, as R8 has not energised.

When the caller clears the connector switch is released.

Section 17

TWO-WIRE SIDE-SWITCHLESS ROTARY CONNECTOR CIRCUIT (Fig. 42)

Circuits 1 to 5 inclusive are similar to those described in connection with Fig. 41, immediately preceding this.

6. The impulses of the final digit intermittently de-energise R′ and operate the rotary magnet RM in series with R6(E), which energises and remains energised during the impulses. RM steps the shaft and wipers to the terminals of the called number and also opens circuit 9 to R9. The 150-ohm winding wound on top of and in multiple with R6 prevents excessive sparking at the impulse springs of R′.

7. Relay R7(G) energises, also slow to de-energise, and opens the circuit to the private wiper Pr2, so that relay K will not open the rotary magnet circuit, while the private wiper Pr2 passes over busy contacts.

8. R7 prepares the circuit to the 125 ohm starting winding of relay K and closes its own circuit to earth at R2

When the impulses cease R6(E) de-energises, and if the number called is not in use, or belongs to a party having only one line (in which case the Pr1 and Pr2 are strapped together), R6 closes the circuit to the 125-ohm starting winding of K.

9. If, however, the number called belongs to a party having a group of two or more lines (in which case only the terminals of the last line are strapped together), and the first line is in use, earth from the private terminal and Pr2 operates relay R9(J) as soon as the rotary armature restores.

10. Circuit 10 shunts the 125-ohm winding of K so that it will not operate in series with R9(J).

11. The rotary magnet RM, over a circuit to earth at R2, energises and steps the wipers to the next terminals, and also opens the circuit 9 so that R9 de-energises. Circuit 11 to

the rotary magnet is opened and allows RM to de-energise. If this set of terminals is also in use, and is not the last set of a group, the RM will again operate and step the wipers to the next set, and again open the circuit to R9. This will be repeated until an idle line is found, or the last set in a group is reached.

12. If an idle set is found R9 de-energises and opens the shunt 10 from K, so allowing the 125-ohm winding of R12(K) to energise in parallel with the winding of R9, and in series with the bridge cut-off coil of the called line switch.

13. Relay R9 on account of its stiff spring and adjustment will not operate, and thus allows R12 to lock itself through its 1,300-ohm winding, and opens the circuits 7 and 9, and R7 de-energises.

14. The private wiper Pr2 is earthed to make busy the number called to other calling lines, and operates the line switch bridge cut-off relay, which cuts the bridge of the called line switch relay from the called line.

15. The interrupted start is earthed so as to start the ringing interrupter, and opens the RM circuit 6 and 11 so as to prevent further rotation of the switch shaft in case the calling party should again turn the dial.

16. Ringing circuit to the called line from interrupted earthed generator, over the called party's ringing loop and 200-ohm winding of relay R16(F).

The back contact of the generator interrupter relay is connected to direct earth, and this alternates on the line with the earthed generator. Relay R16 being marginal, does not energise in series with the ringer and condenser. R16 is made slow to de-energise for the reasons given in the previous circuit.

17. The ringing current induces a current in the 1,300-ohm winding of R16, thus giving the caller an audible signal every time the called bell is rung.

18. When the called party answers R16 energises, opens the ringing circuit 16, and locks itself over the 1,300-ohm winding.

19. The called line is connected to relay R19(D).

Circuit 15 is completed to the starting relay of the ringing interrupter so that the ringing interrupter does not operate while the switch is in the talking position. The interrupter generator circuit 16 is opened so as not to ground the positive wire to the called party.

20. The calling supervisory circuit is closed, but is again opened at R19.

21. R19 reverses the battery to the caller so that the meter, etc., may be operated as described in Fig. 41.

When the called party replaces the receiver first, circuit 19 is opened, R19 de-energises and closes the calling supervisory circuit 20, for use as described in Fig. 41.

When the caller replaces the receiver first, circuit 21 opens, and R′ de-energises, and then R2. Circuit 3 is opened, and the switches on the release trunk de-energise.

22. The release magnet energises, and the switch returns to normal. When the shaft falls the release circuit is opened at the off-normal springs. The battery to the release magnet is taken through a slow acting relay, as and for the purpose before described.

If the individual number called or the last line in a group should be in use, circuit 9 is completed over the strapped earthed private terminals, R6(E) having de-energised when the impulses ceased.

23. Relay R23(H) energises over earth at the strapped terminals over wiper Pr1.

24. Relay R23(H) locking circuit, over earth at R2, instead of from private wiper so

that it will not de-energise and remove the busy signal, if the called number is freed before the caller replaces the receiver.

25. R9 completes a locking circuit for itself.

R12 125-ohm winding is shunted so that it does not energise.

The RM circuits 6 and 11 are opened by R23 to prevent further rotation of the switch.

Circuit 23 is opened at R23(H) so that wiper Pr1 cannot earth, and so busy the number called, after the called party replaces the receiver. Circuit 7 is also opened so that R7(G) de-energises.

27. Busy tone is connected to the positive line of the caller, as before described.

Relay R7(G) de-energising opens the locking circuit 25 to R9 so as to allow R9(J) to de-energise.

The caller cannot come in on the called number as R12(K) has not operated.

When the caller replaces the receiver the switch is released as before.

Section 18

THE CIRCUITS OF THE AUTOMATIC TELEPHONE MANUFACTURING CO.'S SYSTEM AS USED BY THE BRITISH POST OFFICE

Figs. 43–46 show the circuits of a 1,000-line installation of that system modified to meet the Department's particular conditions.

One selector only is shown for the sake of simplicity and to make the diagram more compact. A second selector, in every way similar to that shown, can be added to make the installation suitable for 10,000 lines. By adding a third selector the capacity is raised to 100,000, and by adding a fourth the capacity is raised to 1,000,000. The actual capacity is slightly less in each case, as the first 100, 1,000 or 10,000 numbers may not be used, to avoid numbers beginning with 0 or 00 and the like. The final number of the capacities specified are not used (*e.g.*, 1,000 becomes 999) and they are, therefore, often spoken of as 3-, 4-, 5- and 6- digit systems respectively.

To increase the access to trunks at the preselector or predigit stage, and to provide greater flexibility, primary and secondary line switches, or preselectors, are used in all busy and large installations. Special features will be pointed out when dealing with the circuits. These are numbered in the order of operation and are as follows. —

1. When the receiver (Fig. 43) is lifted to call the line relay LR is energised. This is made slow to de-energise to maintain certain circuits until they can be completed at another point.

2. Line switch LS is energised through its 45-ohm winding and both armatures pull up. Plunger enters banks. LR circuit 1 opened.

3. The subscriber's loop is now extended to the bank springs of the secondary line switch SLS (Fig. 44).

4. Relay R4 is energised through the meter winding. Meter does not operate.

5. The open main feed relay OMF energises and short circuits its 2,775 ohm winding. Relay R5 energises, also secondary line switch. Relay R5 connects bridge cut-off, or holding winding, BCO of primary line switch PLS, and high resistance coil of meter relay MR to earth.

6. Two windings of the secondary line switch (SLS) magnet are in series and the plunger is thrust into the bank. Relay R5 de-energises.

7. Subscriber's loop is extended to relay IR of selector, which energises.

8. Guarding relay G energises, also supervisory relay R8.

9. Holding circuit for PLS magnet.

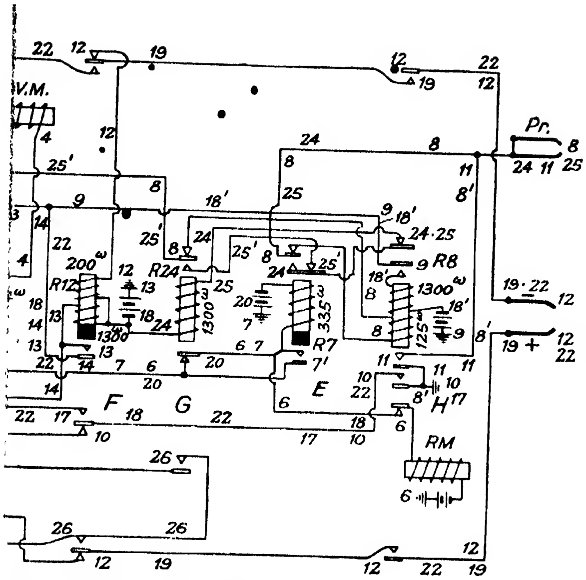
10. Circuit (partly over 9) through meter relay MR, which does not operate, as current is also through the line coil (circuit 3) in opposition.

11. Relay R4 energising also completes a circuit to PMS start relay StR to cause master switch MS to move all plungers opposite the next idle line. Circuits 11 and 5 connect relays StR and OMF in parallel. The 2,775 ohm coil of the latter enables the relay StR to operate with precision.

12. Locking relay Lk energises. Pin withdrawn from master switch quadrant.

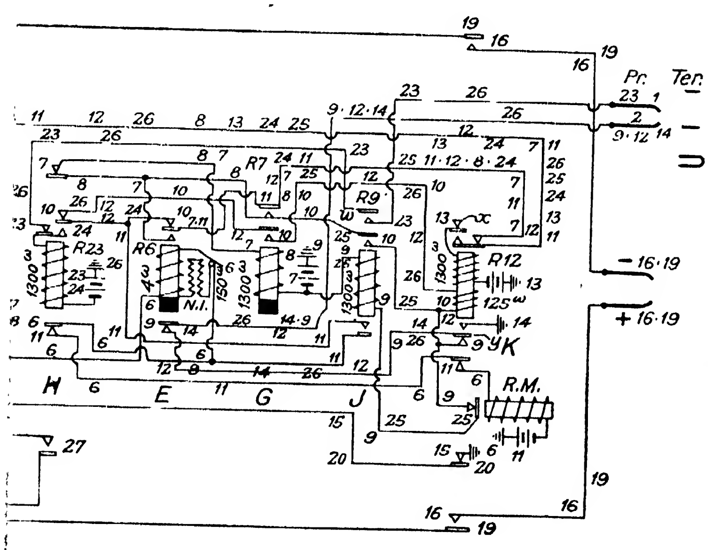
13. Slow relay R13 operates to cut the open main from the line switch. There is no calling while the master switch is operating.

14. When the master switch has stepped the *plungers* beyond the last bank contact,



TOR CIRCUIT. SIDE-SWITCHLESS.

Notes.—Adjust contacts on relay H to make first. Adjust arm. spring on relay F so that it will just pull over against its make contact with 48 volts through res. across 200ω winding but not through 2050ω res. Pr. wiper must find main battery to cut through



RY SIDE-SWITCHLESS CONNECTOR.

Notes.—Adjust arm. spz on relay F so that it will just pull over against its make contact with 48 v. through 1950ω across 200ω winding but not through 2050ω.

Springs of Int. relay J to be stiff.

Contact x on relay K to make first, contact y next, contact w on relay J to make first. Int. springs on R M to break after double dog falls in.

the arm 1 closes the circuit of the trip magnet TR which energises. At next call the start relay StR energises (circuit 11). Locking relay Lk energises (circuit 12). Relay R13 energises. Relay R13 delays the operation of any line switch until an idle trunk is associated. The possibility of double connections is thereby reduced to a minimum.

15. The solenoid *Sol.* energises to carry the shaft and plungers to the opposite end of the banks. (In passing all idle plungers engage with the shaft.) Relay StR de-energises and the trip relay is released by the arm 10 to open the circuit to the solenoid, when the plungers move opposite an idle line.

16. Retaining circuit of start relay StR.

17. Supervisory relay SG energises should the pin mount on the teeth of the quadrant, the locking relay Lk then being operated mechanically. This provides an alarm against unsatisfactory working of the master switch.

18. Alarm circuit on blue lamp and tell-tale.

(For mechanical details of master switch see Fig. 34.)

19. Circuit 9 is extended to the start relay StR of secondary master switch, which energises when the plunger enters the bank, to step all idle plungers to next idle trunk. The secondary master switch operates in the same manner as the primary master switch just described.

20. If all first selectors of a group are busy, it is necessary to connect all idle primary line switches to other groups having idle first selectors. Relay StR is kept energised by the line switch hunting, and the open main cut off relay (which is normally energised) de-energises. All primary master switches associated with this all-busy secondary master switch will be energised, to move to an idle group of secondary line switches, which secondary line switch relays are not operated in this condition.

21 As each trunk to a first selector is engaged, a chain relay R21 is energised (partly over circuit 9).

22 When all the 10 trunks are busy and the associated chain relays energised, the *stop* relay is energised. The stop relay by opening circuit 5 cuts battery off the secondary line switches and master switch.

23. Rotary switch relay R23 energises.

24. Locking circuit of R23.

25. Relay R25 energises.

26. Relay R26 energises to open circuit 25, and relay R5 and the rotary magnet Rot. de-energise. The wiper is thus stepped round.

27. Earth is connected to the wiper, and thereby to each terminal in turn. Each terminal is connected to a start relay StR of each primary master switch having access to this group of secondary line switches and enables each primary master switch to rotate completely. Relay R26 is made slow to release, to enable the primary line switch shaft to pick up all idle line switch plungers.

28. When the wiper reaches the last terminal contact *b* is closed and R28 energises.

29. The release magnet *Rel.* energises and restores all relays to normal. One rotary switch is provided for each 10 secondary groups. If any of the 10 groups still test busy the rotary switch will again operate to restore the idle line switches.

30. Relay SvR energises, with both windings in series, when locking relay LkM energises.

First digit impulses (Fig. 45). Circuit 1 is opened intermittently accordingly to the value of the digit called, and relay IR de-energises accordingly.

31. The vertical magnet VM energises and steps up the shaft to the level associated with the digit called. Relay R31 energises for the duration of the impulses.

32. Relay R32 energises.

33. Holding circuit of relay R32.

After the impulses relay R32 de-energises.

34. Rotary magnet RM energises to move wipers to first terminal and also opens contacts R and S so that circuits 34 and 33 are opened. If the first trunk is busy relay R32 will remain energised over wiper P, and rotary magnet RM will de-energise. Circuits 34 and 33 are again closed, and if the next line is busy, RM will again energise and open contacts R and S and then close them, and so on until an idle line is found. Relay R32 and rotary magnet will then de-energise.

35. Switching relay R35 energises to extend the calling line to the connector. Relay G is slow to release, to maintain the circuit until the line is extended, to put earth on guard wire at connector.

36. Loop 1, 3, 7, extended to impulse relay R36 (Fig. 46) which energises.

37. Guarding relay R37 energises.

38. Guarding or holding circuit. Relay R38 energises.

38′. Holding circuit of relay R38. Upper winding of R38 short-circuited.

Second digit impulses (Fig. 46). Relay R36 de-energises and re-energises according to the number of the impulses of the digit.

39. Vertical magnet VM energises and steps up the shaft a corresponding number of levels. Relay R39 energises for the duration of the impulses.

40. Private magnet PM energises for the duration, as above.

After the impulses relay R39 and private magnet PM de-energise, and the side switches are tripped to the second position.

Third digit impulses.

41. Rotary magnet RM energises and steps wipers a distance corresponding to the impulses of the digit. Relay R39 energises for the duration, also private magnet PM (circuit 40).

After the impulses relay R39 and PM de-energise and the side switches are tripped to the third position if the called line is idle.

42. The called line line-switch LS′ pulls up one armature to cut off the line relay LS′. Earth on terminals from side switch guards the line against other callers.

43. Relay R43 energises.

44. Ringing circuit (circuit alternately earthed over 44′).

Relay R44 does not energise.

When the receiver is lifted to answer R44 energises.

45. Relay R45 energises to supply current to the called microphone.

46. Windings of relay R36 are reversed to calling loop, which reverses the current in the calling loop. The currents in meter relay windings are now in the same direction and MR energises.

47. Meter M registers one call.

48. The meter winding in the line circuit is short circuited.

Microphone current for the calling subscriber is through relay R36, for the called subscriber through R45.

If the called subscriber had been engaged the private wiper P would be earthed.

49. With side switches in the second position relay R39 would de-energise after the third digit impulses, but circuit 49 would be completed before circuit 40 was broken, and PM would remain energised in series with relay R49, which would energise. The side switches would not move to the third position.

50. Retaining circuit of relay R49

51. Busy signal to calling subscriber.

As the side switches did not move, relay R43 would not energise to join up the line wipers.

52. When the calling receiver is replaced, the connection is broken down by the release magnet *Rel.* energising. Relay R52 energises to glow lamp RS (green) as a clearing signal.

53. Should the called receiver be replaced first, and the calling subscriber delay to clear, lamp AS (white) will glow as an alarm signal.

When a call is from a subscriber connected to a manual board, current for the called microphone is fed from the cords, and all connector bridges are cut out off circuit. The holding circuit 38 is earthed at the cord, and this, with the earth at the upper contact of relay R37, short-circuits the 25-ohm winding of relay R38, which cannot therefore energise.

54. Switching relay R54 energises over the holding wire and earth at the cord.

55. The line from the manual board is now extended directly to the line wipers without bridges or condensers, and the control is in the hands of the operator.

The withdrawal of the cord de-energises relay R54, and the release circuit is completed as before described.

56. If the line called is engaged, a lamp-flashing signal is given by the supervisory relay and lamp on the cord, partly over circuit 51.

The subscribers control the supervisory signals as in manual practice.

Section 19

KEITH LINE SWITCH AND ROTARY CONNECTOR CIRCUITS

For smaller and less busy installations, a single line-switch is used. This is shown at Fig. 47 in combination with a rotary connector, Fig. 48. Such a combination may be used in small offices, but is used here simply for illustrative purposes.

A rotary connector may be rotary on one level or all levels. It is used to connect with one of a plurality of lines, serving a private branch exchange, which have one common calling number. A level may contain lines to more than one branch exchange. In Fig. 48 the private terminals of three such groups are shown. A double row of terminals are required, but all except the last of each group of the upper row are insulated and not used. The last upper and lower terminal are looped together as shown. For the second last digit the shaft rises vertically in response to and according to the number of the impulses in the usual manner. For the last digit the wipers rotate step by step, according to the number of impulses in the digit, to reach the first terminal of the group, then, if that and adjacent lines are engaged, the wipers will step automatically until an idle line is found.

The switch is thus a combination of a selector and a connector.

The circuits are numbered in the order of operation and are as follows :—

1. When the receiver is lifted to call, the line relay LR is energised. LR is made slow to de-energise to maintain the circuit until it is completed at the selector or connector.

A. T. M. CO.'S SYSTEM AS USED BY BRITISH POST OFFICE.

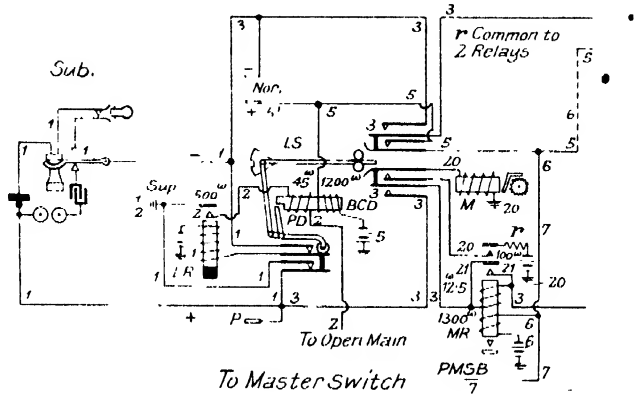


FIG. 47. KEITH LINE SWITCH.

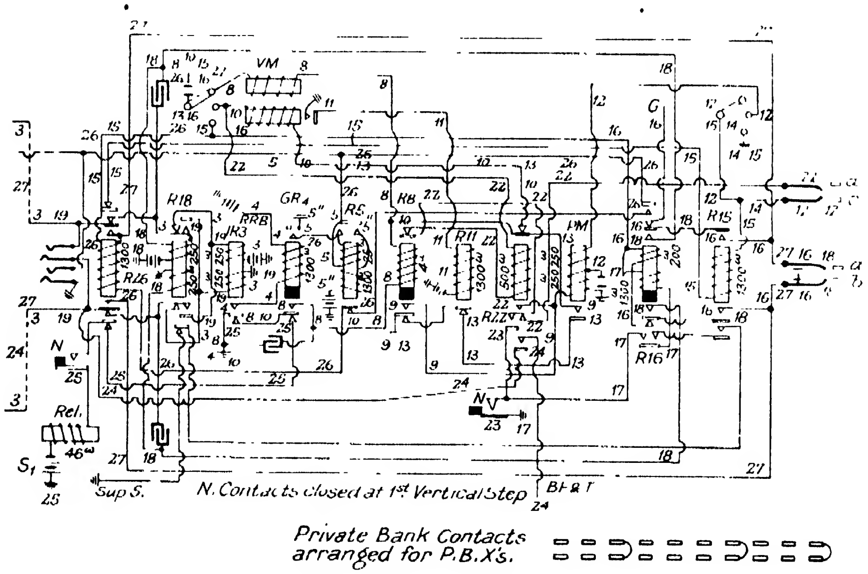


FIG. 48. ROTARY CONNECTOR.

2. The pull-down winding of the line switch LS is energised to thrust the plunger into the bank of contacts of a preselected trunk. LR de-energises and circuit 2 is opened.

3. The loop 1 is extended to the relay IR3 of the connector which energises.

4. Relay GR4 energises. This relay is slow to de-energise, and maintains the guarding, holding and release circuits during a train of impulses.

5. Holding circuit for the line switch LS through the bridge cut-off coil BCO. Relay R5 energises.

5′. Guarding potential on private bank contacts to prevent another calling line interfering.

5″. Holding circuit of relay R5.

6. Circuit through meter relay MR. Current in line circuit winding 3 is in opposition. MR, therefore, does not energise. (Partly over circuit 5 to GR earth.)

7. Circuit to master switch bank (not shown, see Fig. 43) partly over circuit 5.

First digit impulses. Relay IR3 de-energises and re-energises in a manner corresponding to the number of impulses in the digit called, and intermittently makes and breaks circuit 8.

8. The vertical magnet VM steps up the shaft and wipers to the level corresponding to the digit. Private magnet relay R8 energises for the duration of the impulses. The normal contacts are closed on the first step.

9. The private magnet PM energises for the duration of the impulses.

After the impulses, relay R8 and private magnet PM de-energise, and the side switches are tripped to the second position.

Second digit impulses. Relay IR3 operates as before.

10. The rotary magnet RM steps the wipers round a distance corresponding to the impulses of the digit. Relay R8 energises then PM (circuit 9).

11. Relay R11 energises on each energisation of the rotary magnet RM. After the impulses R8 and then PM de-energise if the first line of the group is idle and the side switches are moved to the third position.

12. If the first line of a group is busy, terminal C will be connected to earth by its associated relay GR. The private magnet therefore will not de-energise.

13. The rotary magnet RM will again energise over a new circuit. Circuit 11 will be again completed, and relay R11 energised to open circuit 13 to de-energise the rotary magnet. The wipers will thus be stepped to the next terminals. If that line is also busy, the private magnet will remain energised, and the rotary magnet again step, and so on until an idle line is found. The private magnet will then de-energise and trip the side-switches to the third position.

14. Earth to make busy the line connected.

15. Relay R15 energises.

16. Ringing current circuit to the bell of the called line, relay R16 does not energise. When the receiver is lifted to answer, R16 energises.

17. Retaining circuit of relay R16.

18. Battery feeding circuit to called subscriber. Relay R18 energises.

19. Relay R18 reverses the connections to relay IR3, and the current in the calling subscriber's loop is consequently reversed. The currents in the two windings of the relay MR are now in the same direction, and relay MR energises.

20. The meter M now energises, and registers one call against the caller.

21. The line winding of the relay MR is short-circuited.

22. If all the lines in the particular group serving the P.B.X. called had been busy, relay R22 would energise over the looped end terminals (partly over circuit 14).

23. Holding circuit of relay R22 and private magnet PM. As PM does not de-energise, the side-switches do not move to the third position.

24. A busy tone is given to the calling subscriber. If the connection had been made through a manual board, a lamp-flashing signal would be given over the same circuit (see Fig. 46).

25. When the calling receiver is replaced after conversation, the loop 1 is opened and relay IR3 de-energises, circuit 4 is then opened and GR4 de-energises. The holding circuit 5 being then opened, the line switch BSO coil de-energised, and the switch is restored to normal. IR3 and GR4 complete a circuit for the release magnet which energises to restore the switch, and again open normal contacts N.

If the call has been made through a manual board, circuit 5 would be earthed at the cord, and relay R5 would not energise.

The connector is operated as before described to call a line.

26. With the side switches in the third position, relay R26 energises

27 The subscriber's loop 1 and 3 is then extended directly to the wipers without condensers or bridges, and microphone current for the called party is from feeder-bridges in the cord.

Clearing. The withdrawal of the plug opens the loop, and IR3 and GR4 de-energise to release the connection as before

Section 20

REPEATER WORKING

Repeater in an Outgoing Trunk between two Automatic Offices. Direct impulsing, through intermediate offices, has not been found satisfactory in practice, owing to the impulses losing their sharpness and just as long telegraph and other lines have to have their currents relayed, so automatic impulses have to be relayed or repeated

At the distant end of a trunk a relay is introduced which responds to the makes and breaks of the dial sender, and usually this same relay opens and closes a new loop circuit which extends to the office beyond. The impulse currents may be repeated a second and third time as required.

Fig. 49 shows a repeater circuit as used by the British Post Office.

A bridge is connected across the loop at the selector end of the trunk, which completes a circuit for a relay at the distant end, which responds to the openings and closings of the bridge in response to the dial impulses This bridge also connects the condensers together to prevent their discharging into the circuit In some circuits the condensers are entirely cut off from the outgoing trunk whilst impulses are being sent.

The circuits are numbered in the order of operation and are as follows :

1. The loop is extended from the selector banks, or other switches, and impulse relay IR′ energises.

2. Guarding relay GR2 energises and remains energised during impulsing.

3. Holding and busying circuit for prior switch.

4. Circuit completed through relay R4 which, however, does not energise owing to the currents in the two windings opposing each other.

5. Loop completed over trunk to distant office, through relay R4 and retardation coil RC. The local circuit through R4 holds it energised when the loop circuit is opened.

When digit impulses are sent relay IR′ de-energises and re-energises, according to the value of the digit.

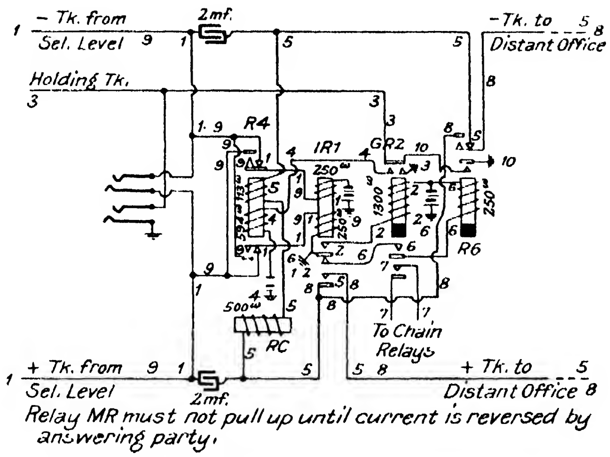


FIG. 49. REPEATER FOR OUTGOING TRUNK AUTO TO AUTO.

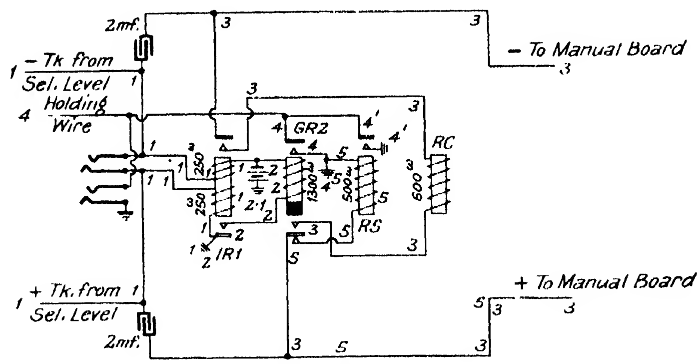


FIG. 50. REPEATER FOR OUTGOING TRUNK TO MANUAL BOARD.

6. Relay R6 energises on the first de-energisation of IR′ and remains energised for the duration of the impulses.

7. The associated chain relay energises when relay R2 energised. All chain relays energised indicate when all trunks of a group are busy.

8. Circuit 5 is opened at relay R6, and a new loop circuit closed and opened at IR′ for impulses to trunk. After the impulses R6 de-energises and circuit 5 is again completed.

When the current is reversed at the connector by the subscriber answering, the currents in relay R4 are then in the same direction and R4 energises.

9. The windings of relay IR′ are then reversed, and current in the calling subscriber's loop reversed to operate the meter, etc.

The talking circuit is from loop 1 to loop 5 through the condensers.

Microphone current for the caller is from relay IR′. The called party draws battery from the connector.

10. When the calling subscriber clears, IR′ and GR2 de-energise; relay R6 energises and maintains earth on the holding circuit for a brief period to ensure all switches being released.

Repeater on Outgoing Trunk between an Automatic Installation and a Manual Board (Fig. 50.)—1. Line extended from a selector to impulse relay IR′, which energises.

2. Relay GR2 energises.

3. Circuit through manual board completed through retardation coil RC

4. Holding and busy circuit for prior switch.

The digit impulses de energise and re energise relay IR′.

Circuit 3 opened and closed intermittently to send impulses to line.

5. When the caller clears relay IR′ and GR2 de-energise. Relay R5 energises to maintain earth on guarding wire 4′, until switches release

Section 21

TRUNK OFFERING CIRCUIT

A ticket is made out for each demand for the use of a trunk or toll line, and when a toll line becomes idle the call is reversed, and the original caller is now called by the trunk operator. Between these periods the caller may have initiated another call, or he may have been called by another party and his line now tests engaged. Again, a party engaged in a local connection may be required for a trunk call from another exchange and he has to be given the option of abandoning the local call and taking the trunk call. The operator must therefore be able to make connection with an engaged circuit and offer the call, and when the caller of the local connection replaces the receiver (if he is the party wanted), the local connection must be severed. The operator then releases the offering circuit and completes the connecting over the regular circuits.

In small exchanges it may be sufficient to call two digits on the offering connector, but in larger exchanges it is advisable to keep the calling uniform for all types of calls and dial the full number. A distributor or 2 digit selector is used in addition to the connector. This arrangement is shown in Fig. 51 and the circuits are numbered in the order of operation and are as follows :—

1. A plug is inserted in the jack at the trunk exchange and relay R′ energises.

2. Relay R2 (slow to de-energise) energises.

3. Distributor engaging circuit.

First digit impulses sent.

4. On the first break relay R4 and the vertical magnet M4 energise. R4 is energised for the duration of the train of impulses.

Magnet M4 lifts the shaft to the level associated with the digit.

5. Private magnet M5 energised.

After the train of impulses relay R′ remains energised when circuit 4 is opened so that R4 de energises. R5 then de energises and the side switches move to the second position.

Second digit impulses.

6. On the first break circuit 4 is extended over circuit 6, in which R4 and the rotary magnet M6 are energised. The wipers are carried round the arc a distance corresponding to the digit.

M5 is again energised in circuit 5.

After the train of impulses R′ remains energised and R4 de-energises.

7. If the connector is busy a circuit will be completed for M5 over side switch A in second position, so that M5 does not de-energise and the side switches, therefore, are not moved to the third position.

8. Relay R7 is energised and held over the shaft off normal contact.

9. Busy flash circuit to calling line.

If the connector is idle the private magnet M5 de-energises after the second digit, and the side switches move to the third position.

10. Relay R10 energises.

11. Trunk extended to the connector and relay R11 energised.

12. The third conductor P is extended to earth at connector after relay R13 energises.

13. Relay R13 energises.

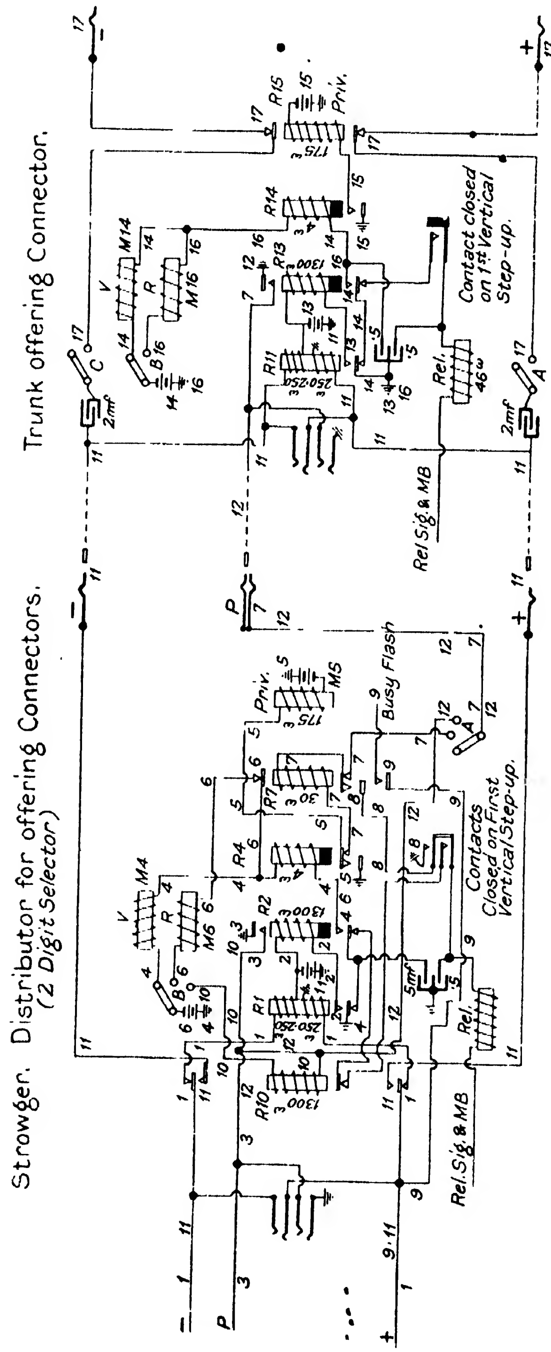


FIG. 51. TRUNK OFFERING CIRCUIT (A. T. M. Co.)

Relays R′ R2 de-energise. All the selector apparatus is cut from the line to the connector.

Third digit impulses :—

14. On the first break relay R11 de-energises. Relay R14 energises in series with vertical magnet M14, and the shaft steps up the wipers to the associated level.

15. Private magnet R15 energises and opens the line circuit to the wipers.

After the train of impulses relay R11 remains energised and circuit 14 is opened : therefore, relay R14 de-energises, then R15. The latter allows the side switches to pass to the second position.

Fourth-digit impulses.

16. On the first break relay R14 is again energised, in series with the rotary magnet M16. M16 rotates the wipers a distance corresponding to the value of the digit.

After the train of impulses relay R14 de-energises, then R15.

17. The trunk line is extended to the wipers. It is to be noted that no connection is made to the test circuit, or third conductor, and that the line wires connected to the local circuit are insulated. The operator can, therefore, offer the trunk call and, if accepted, the hanging up of the local caller's receiver will release the connection in known manner.

Relay R11 remains across the loop on the trunk side of the condensers, and relay R13 remains energised. When the offering plug is withdrawn the connection is released in known manner.

Section 22

TEST CLERK'S CONNECTOR, FOR INWARD CALLS (Fig. 52)

This is for general work, and is also used for testing dials from subscribers' offices.

The circuits, numbered in the order of operation, are as follows :—

1. When a connection is extended through the general system, relay R′ is energised.

2. Relay R2 energised.

3. Line engaged.

Tens digit impulses received.

4. On the first break relay R4 energises in series with the vertical magnet M4, and the wipers are stepped up to a particular level.

5. Private magnet M5 is energised.

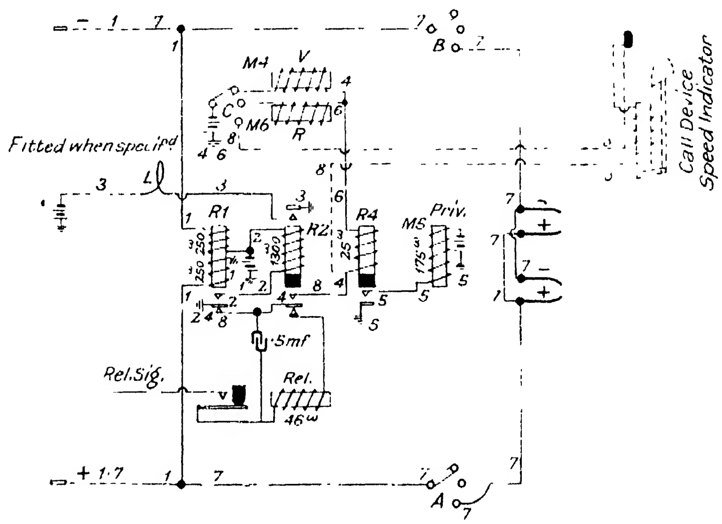


FIG. 52.—TEST CLERK'S CONNECTOR CIRCUIT

After the train of impulses, relay R4 de-energises, then M4, when the side-switches pass to the second position.

Units impulses received.

6. On the first break R4 energises in series with the rotary magnet M6, and the wipers are stepped round to a particular set of terminals.

M5 again energises in circuit 5.

After the train of impulses R4 and then M5 de-energise, when the side-switches pass to the third position.

7. The line circuit is extended to double wipers. Relay R′ is a bridge across the loop. R2 remains energised.

8. Additional trains of impulses may now be received on the speed tester.

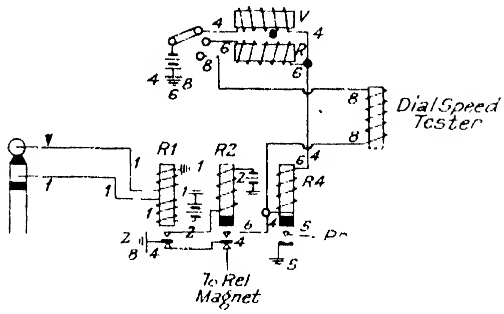


FIG. 53. DIAL SPEED TESTING CIRCUIT.

Plug circuit for dial speed testing (Fig. 53).

This circuit is similar to the above, and the circuits are similarly numbered. The relay R′ is connected to the plug with the earthed winding connected to the tip.

DIRECTOR OF INDUSTRIES
LIBRARY
13-JUL. 1925
BENGAL

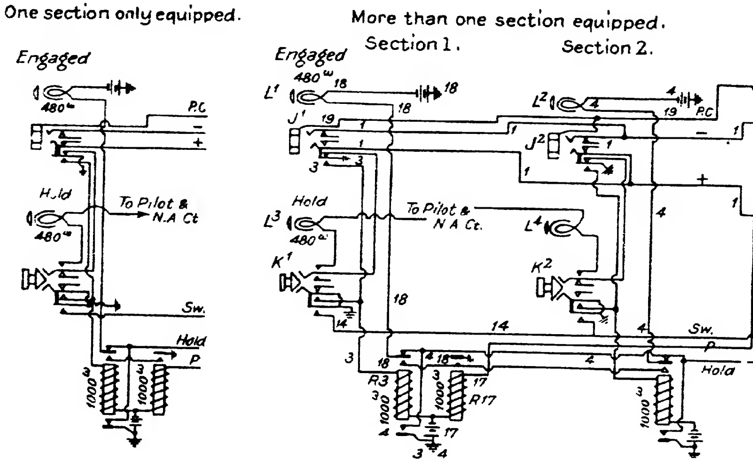


FIG. 54.—POST OFFICE (A. T. M. CO.) TEST DESK CIRCUITS.

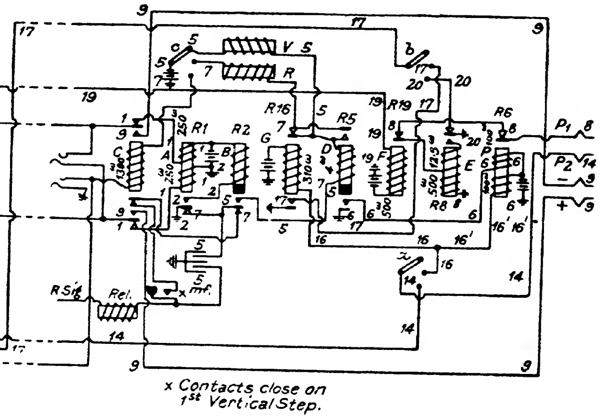


FIG. 55.—A. T. M. CO.'S TEST DESK DISTRIBUTOR (FOUR WIPERS).

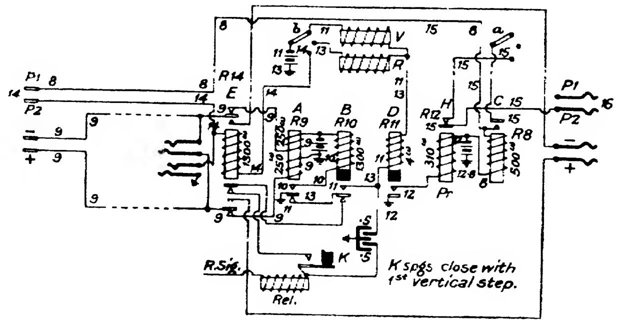
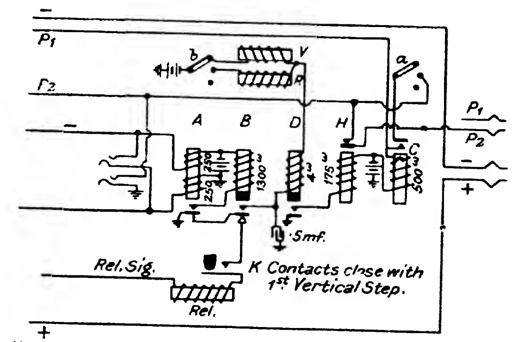


FIG. 56.—TEST DESK CONNECTOR.



NOTE – Adjust spider arm stop to prevent side switches passing to 3rd position.

FIG. 57.—TEST DESK CONNECTOR (FOR USE WITHOUT DISTRIBUTOR).

Section 23

TESTING EQUIPMENT IN AUTOMATIC SYSTEMS, A. T. M. CO. (Fig. 54-61)

For making insulation, resistance, and other well-known tests, in automatic systems, it is necessary to provide selectors and connectors that cut off all operating mechanism, and leave circuits from test jacks, over selectors and connectors, to the subscribers' lines as clean metallic circuits without bridges and the like.

For exchanges having a capacity of from 2 000 to 3,000 lines, connectors may be wired to the test board, and the lines be called by plugging into jacks associated with the particular 100 required, and then dialling the tens and units digits only. This is not satisfactory for large offices, and two digit selectors, or distributors, are used, one connected to each testing position, which, in response to the first two digits of a four-figure number, connects with a particular connector. For systems of over 10,000 lines such four-figure equipments are provided for each 10,000 lines.

One test connector is provided for each 100 subscribers' lines.

When the test board has more than one position, the equipment lines are multipled on the different positions or sections with lamps, to indicate lines busy on other positions.

On the left of the diagram (Fig. 54), a single position test desk is shown.

A two-position desk is shown wired to a distributor and a connector.

The circuits, numbered in the order of operation, are as follows:

1. When a plug is inserted into a jack, say J', relay R' energises.
2. Relay R2, slow to de energise, energises.
3. Relay R3 energises.
4. Lamp L2 glows, to show multiple line engaged on other positions. The home lamp L' does not glow.

First digit impulses sent (Fig. 55).

5. On the first de energisation of relay R', relay R3 energises for the duration of the train of impulses, and the vertical magnet V steps the wipers up to the level corresponding to the digit called.
6. Private magnet R6 energises.

After the train of impulses relay R' remains energised, R5 de-energises, then relay R6.

The side switches are then caused to move to the second position.

Second digit impulses.

7. On the first de-energisation of relay R', relay R5 re energises for the duration of the train, and the rotary magnet R moves the wipers round to the terminal corresponding to the digit called.

Relay R6 re-energises in circuit 6.

After the train of impulses R' remains energised, R5 de-energises, then R6, and the side switches move to the third position.

8. Relay R8 energises over P'', to connect P' to side switch arm *a*.
9. A clean metallic circuit from jack through distributor, and relay R9 (Fig. 55) energises.
10. Relay R10, slow to de-energise, energises.

Tens digit impulses (Fig. 56).

11. On the first de-energisation of relay R9, relay R11 energises for the duration of the impulses, and the vertical magnet V steps the shaft up to the desired level.

12. Private magnet R12 energises.

After the train of impulses relay R9 remains energised, circuit 11 is opened and R11 de-energises, then R12. Side-switches step to the second position.

Units digit impulses.

13. On the first de-energisation of relay R9, circuit 11 is again closed, and relay R11 energised for the duration of the impulses, and the rotary magnet R steps the wipers round to the corresponding set of terminals. Circuit 12 is again closed, and R12 energised.

After the train of impulses, R11 de-energises, then R12, and the side-switches are stepped to the third position.

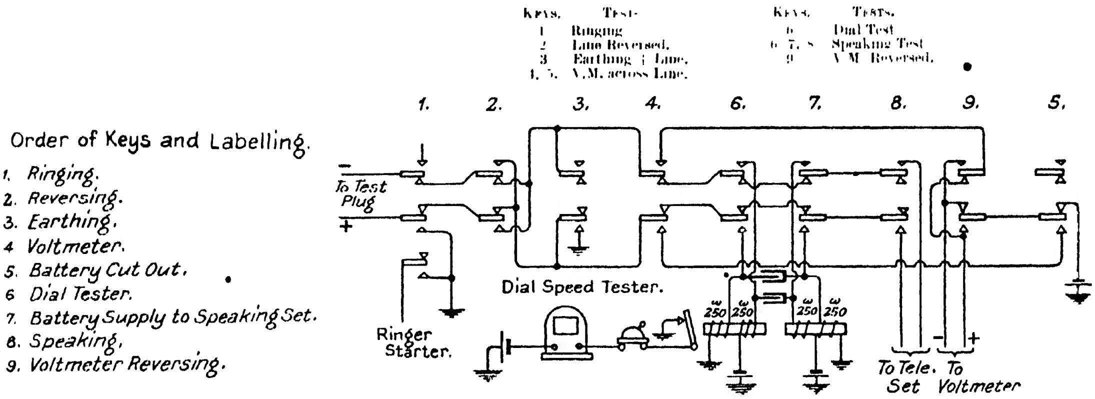


FIG. 60. POST OFFICE TESTING CIRCUIT FOR SMALL AUTOMATIC OFFICES (A. T. M. CO. SYSTEM).

14. Relay R14 is energised, over depressed holding key on test board, to extend a clean metallic circuit from the test jack to the connector wipers for testing purposes.

15. Subscriber's cut-off relay energises over P2 and circuit 8, to busy the called line.

16. Should the connector be busy (after circuit 8), the side switches *a* and *b* are in the second position, and relay R16 energises.

17. Relay R17 energises.

18. Lamp L′ glows as a busy signal.

The private magnet R6 is held energised over circuit 16′, and the side switches are prevented from moving to the third position.

19. For internal tests a key in the plug sleeve circuit can energise relay R19. Circuit 8 is then opened, and relays R8 and R8′ de-energise 20. Circuit 17 is then earthed over 20 and relay R17 energises, and lamp L′ glows.

If the subscriber's line called is engaged, relay R8′ will be short-circuited, and circuit 20 will be completed, and signal given, as before described. The party testing may listen in, but will delay the test.

Fig. 57 shows a connector for use without a distributor. The circuits will be readily understood from the description of the connector circuits (Fig. 56).

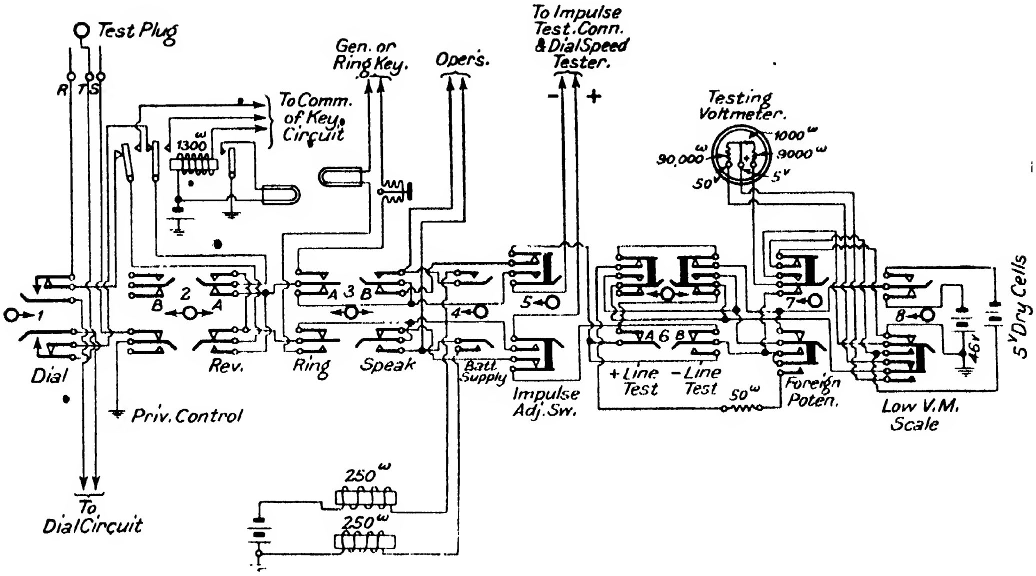


FIG. 58.—POST OFFICE TEST DESK KEYBOARD CONNECTIONS.

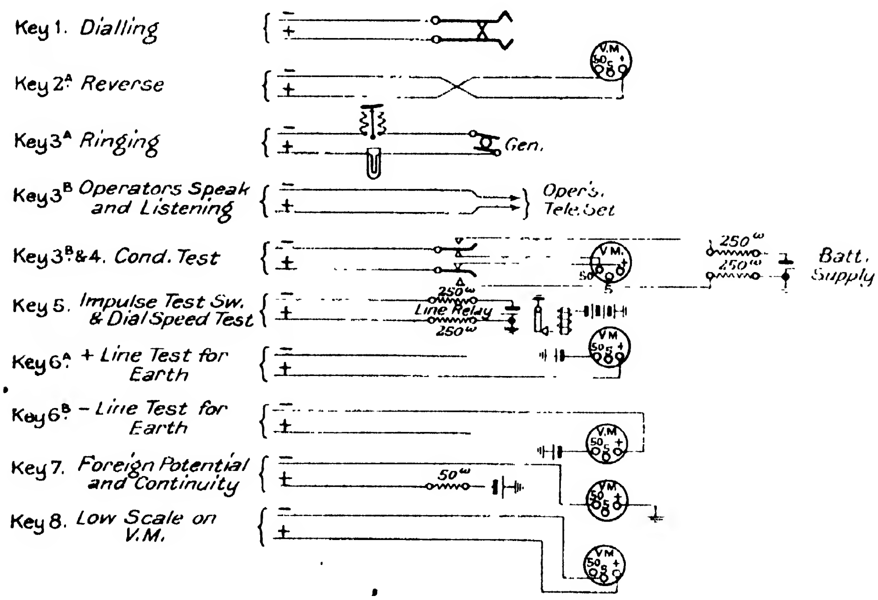
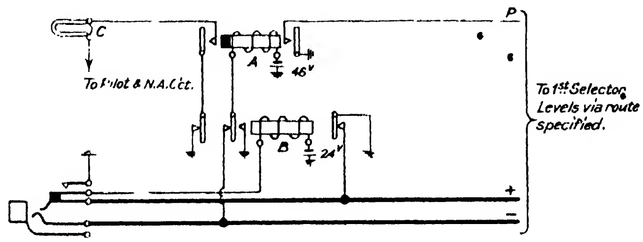


FIG. 59. TEST CIRCUITS FOR TEST DESK KEYBOARD.

Fig. 58 shows keyboard circuits on a test desk; and in Fig. 59 is shown, in simple diagrams, the tests that can be made, and the association of the different keys.



	T.A.362A Mixed Voltages		T.A. 550A
	24V	46V	46V
A		500ω	1000ω
B	500ω		1000ω
C	240ω		480ω

FIG. 61.—TEST DESK. FAULTSMEN'S INCOMING LINES (A. T. M. CO.'S SYSTEM).

Fig. 60 is a testing circuit for small automatic exchanges. This is self-explanatory.

Fig 61 is a circuit of a faultmen's incoming line on the test desk. This will be readily understood without description.

Section 24

TEST OF CONNECTORS USING TESTER NO 11a (Figs. 62, 63)

The test of a connector entails the connecting of the wipers to one of the bank contact sets, and for this purpose the "99" contacts on each connector are utilised, whether a working line is connected to these contacts or not. On each connector unit a single jack with associated lamp is provided, and connected in such a way as to meet the requirements of the test and at the same time, practically, to eliminate interference with traffic to or from the "99" line.

Before commencing the test, the plug on the tester is inserted into the "99" jack, *but it is important that this be not done until it has been definitely ascertained that the "99" line is not engaged on an incoming call*, otherwise the call will be interrupted. It will be necessary therefore to inspect each connector on the unit, including the trunk offering and test connectors, to ascertain that none of them are connected to the "99" line. When this has been verified the plug may be inserted.

The insertion of the plug will not interfere with a call originated by the "99" subscriber, and no steps need be taken to ascertain whether the line is engaged on an originating call.

During the period of the test, from the moment of inserting the plug into the "99" jack to the moment of its withdrawal at the completion of the test, the following precautions

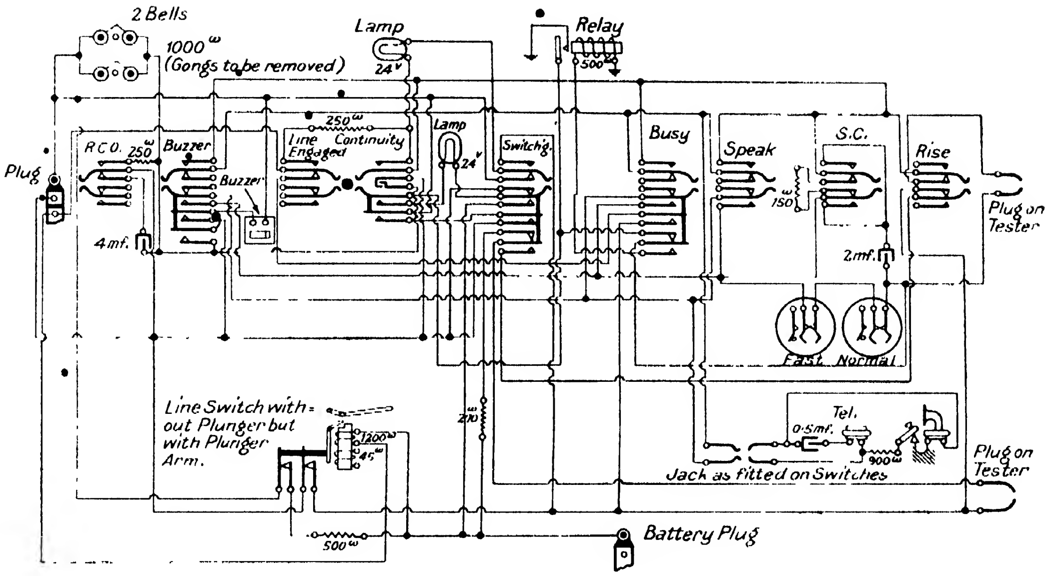


FIG. 62. POST OFFICE TESTER NO. 11A

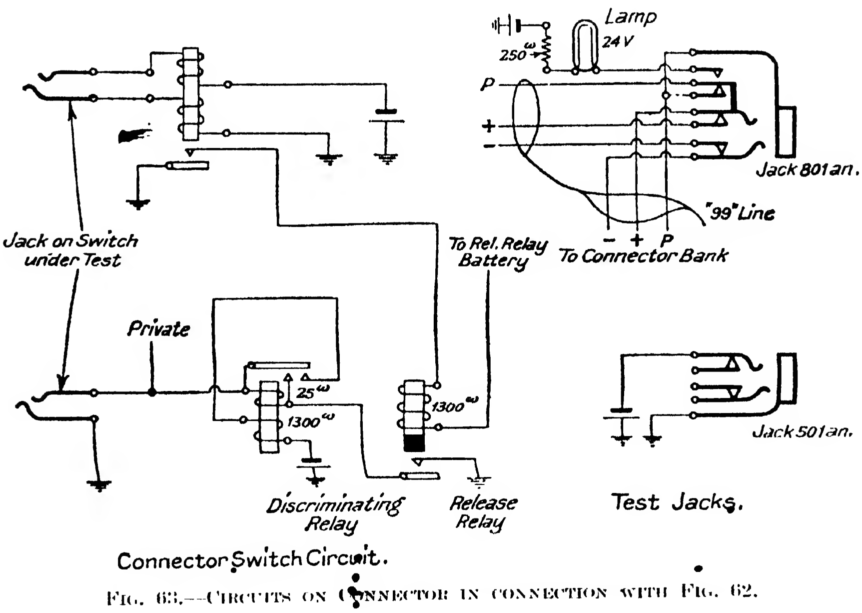


FIG. 63.—CIRCUITS ON CONNECTOR IN CONNECTION WITH FIG. 62.

must be taken to ensure the minimum of interference with the service to and from the " 99 " line :—

When a call is made from any source to the " 99 " line, then, unless the connector under test actually has its wipers on the " 99 " contacts, a ring will be received on the tester. The testing officer will then ascertain, by glancing at the lamp associated with the " 99 " jack, if the " 99 " line is engaged on an originating call. If this lamp is glowing, signifying that the " 99 " line is engaged on an originating call, the plug must on no account be withdrawn from the " 99 " jack, but the testing officer must find the connector which is calling, and by plugging into the jack on the connector must advise the calling subscriber, or operator, that the number required is engaged. If there is no one on the line at the moment of plugging into the connector jack, as might happen in the case of a trunk call incoming to the " 99 " line, the testing officer must wait on for a reasonable period, but none of the relays on the connector must be touched with the object of calling an operator in, for, should the call be local, this may have the effect of registering a call on the originating subscriber's meter. When the caller has been advised that the " 99 " line is engaged, the testing officer should wait until the connector has been released, and then proceed with the test.

If the bell on the tester rings, and the lamp associated with the " 99 " jack is not glowing, the testing officer should immediately remove the plug and then find the connector which is being used on the call and ascertain by means of a hand set that ringing current is going out satisfactorily, or that the two subscribers are in communication. When this call has been completed and the connector has been released, the plug is inserted into the " 99 " jack and the test is proceeded with.

If a call is made to the " 99 " line whilst a connector under test is standing with the wipers on the " 99 " contacts a calling subscriber, or operator, will get the busy back, although the " 99 " line may not be actually engaged on a call. In this case the testing officer, who throughout the test should be on the alert to recognise by the sound of the impulses when any connector on the unit under test is stepped up and around to the " 99 " contact, must glance at the lamp associated with the " 99 " line and, if this is not glowing—signifying that the " 99 " line is disengaged—should rapidly locate the calling connector and, inserting the plug of a hand set in the connector jack, ascertain if the caller is still on the line, and at the same time remove the busy tone from the line by releasing the switch with a stroke from the release magnet armature. The caller, if still on the line, should be told that " 99 " was being tested, and should be asked to repeat the call, and the testing officer, immediately on making this request, should withdraw the plug from the " 99 " jack and wait for the call to come through again. When the call is completed, and the connector utilised on it is released, the testing officer should reinsert the plug into the " 99 " jack and proceed with the test.

If the testing operator hears a connector being stepped to the " 99 " contacts, and no ring is received on the bell on the tester, due, as explained above, to the wipers of the connector under test being on the " 99 " contacts, then if the lamp associated with the " 99 " jack is glowing, the testing officer need take no notice of the call, but proceed with the test in the ordinary way.

The tests described herein should be made when the amount of traffic is low. When carrying out these tests the fact that a switch passes the electrical tests specified does not prove that it needs no attention, and a close watch should be kept on the switch whilst under test to ascertain that all the mechanical movements are quite normal ; also that there is no excessive sparking at any of the contacts.

Having taken the precautions previously specified with regard to the testing of connectors, the appropriate plug on tester No. 11a is inserted in the " 99 " jack on the relative unit, and the battery plug is inserted in the battery jack on the unit. All the keys on the tester must be in their normal positions, and a hand set connected to the tester by means of the jack provided for this purpose.

I. (*a*) Insert the test plug of the tester into the jack on the connector to be tested, in doing so *note that the discriminating relay* (*C*) *is energised*. Dial " 99 " on the fast dial. The shaft should be stepped up and round smoothly and regularly and, when the wipers come to rest, the bells on the tester should be rung interruptedly. Note that the interruptions are regular, and allow the ringing to persist for a few seconds to insure that the alternating current through the bells and condenser is not sufficient to trip the ringing.

(*b*) Throw and immediately release the ring cut off key (N.C.O.) in the *silent* period of the ringing, and *note that the ring cut off relay is actuated at the same instant* that the key is depressed. Note also that the ringing ceases and that the back release alarm lamp (if any) on the unit glows. This test must be made at an instant when the back release alarm lamp is not glowing, due to the conditions of some other switch on the unit.

(*c*) Throw the release key and note that the switch is smoothly restored to normal. The back release lamp is extinguished unless the alarm conditions are being given by some other switch on the unit. Restore the release key.

Note.—In the following tests the back release alarm lamp will glow occasionally, but this is not referred to as the foregoing test proves all that is necessary.

II. (*a*) Throw the short-circuit key (SC) and dial " 99 " on the fast dial. The bells on the tester should ring. Release the short-circuit key.

(*b*) Throw and immediately restore the ring cut off key in a *ringing* period of the ringing and *note that the ring cut off relay is actuated at the same instant as the key is depressed without any vibration of the relay springs.*

(*c*) Throw the release key to restore the switch to normal. Restore the release key.

III. (*a*) Throw the busy key. Dial " 99 " on the slow dial. Note that the wipers come to rest on the " 99 " contact and that the " busy back " is heard in the receiver.

(*b*) Dial the third " 9 " and note that no movement is imparted to the shaft.

(*c*) Throw the release key to restore the switch to normal. Restore the release key and the busy key.

IV. (*a*) Throw the short circuit (SC) key and dial " 99 " on the slow dial. The bells on the tester should ring. Release the short-circuit key. Momentarily depress the ring cut-off key to stop the ringing.

(*b*) Throw the continuity key ; lamps P and Q should glow with characteristic brilliancy. Any variation in the glow of these lamps from that generally observed when carrying out this test denotes a fault. Restore the continuity key.

(*c*) Throw the line engaged key. Lamp P should glow indicating that the " 99 " line is made engaged by the connector. Restore the line engaged key.

(*d*) Throw the buzzer key and note that a " buzz " of characteristic loudness is obtained in the receiver, proving the continuity of the transmission circuit. This " buzz " will be of sufficient volume to be heard without removing the telephone from the hook on the tester. Any appreciable variation in the volume of this " buzz " from that generally heard on this test denotes a fault (by a wire off a condenser). Restore the buzzer key.

(c) Throw the release key to restore the switch to normal and then restore the release key.

V. (a) Throw the switching key, then hold the release key down for the short period necessary for the shaft to return to normal after having received one impulse from the vertical magnet. This releases the discriminating relay (C) energised on the previous test. Dial "99" on the fast dial and note that the bells ring. Momentarily depress the ring cut off key to stop the ringing.

(b) Throw the continuity key and note that lamps P and Q glow with characteristic brilliancy, although not necessarily identical with the glow observed in IV. (b). Any variation in the glow of these lamps from that generally observed when carrying out this test denotes a fault.

(c) Restore the continuity key and depress the release key to restore the switch to normal and then restore the release key.

VI. (a) With the switching key still thrown, throw the busy key and then dial "99" on the slow dial. The busy back should be obtained in the receiver.

(b) Throw continuity key, lamps Q and P should pass continuously through the following cycle of glows :-

Q. Bright, very faint glow ; bright,
P. Dimmed normal glow , dimmed,

and so on.

(c) Restore the busy key and the switching key and then depress the release key to restore the switch to normal

Section 25

TEST ON SELECTORS WITH THE TESTER NO. 14 (Fig. 64)

This tester is used in connection with the routine test of the selectors on the A. T. M. Co.'s automatic system.

The tester is equipped with the following apparatus .

1 Speaking key for use with a Switch Attendant's Telephone No 80.
1 " Fast " dial.
1 " Slow " dial.
1 Short circuit key for replacing the normal 750ω of the test circuit by a short circuit having a capacity of 2 microfarads.
1 Battery plug for use with the power jack on selector board.
1 Testing plug for use on the selector switch.
10 Two position keys associated with 10 lamps for testing the engaged condition of a group of 10 switches and for making those switches artificially engaged (or guarded) as required.
Ten-way cord for connecting the tester with a level specified on the routine testing schedule.

This tester is used to test a large group of selectors at the same time. The test of all these selectors will be carried out by dialling the same digit, *i.e.*, the tester will during the whole of this time be connected to the same level.

The routine testing scheme for overhauling selectors provides for the 10-way cord of

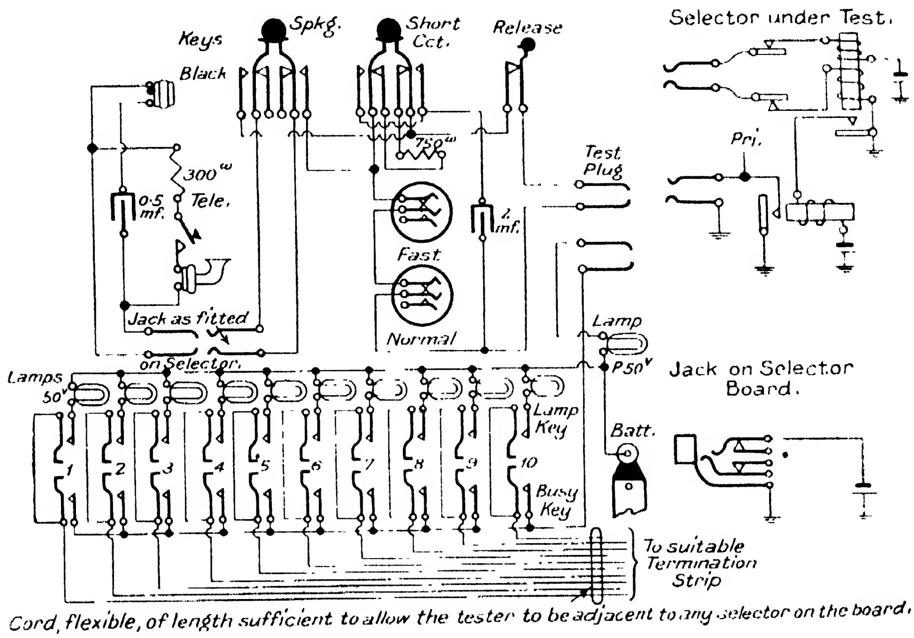


FIG. 64.—POST OFFICE TESTER NO. 14 FOR SELECTOR TESTING.

the tester No. 14 to be moved from level to level so that in a series of tests extending over, say, 12 months, every level will come under test.

The procedure will be as follows :—

(1) Connect the 10-way cord to the level indicated on the routine testing schedule.
(2) Insert the battery plug into the power jack.
(3) Insert test plug into jack of selector about to be tested.
(4) Observe all keys are at normal.
(5) Dial digit of the level chosen using the "Fast" dial.
(6) Pull appropriate key over to "Lamp."
(7) Observe that the corresponding lamp glows.
(8) Depress release key.
(9) Observe that the lamp is extinguished (unless the trunking circuit be engaged upon an actual call).
(10) Throw the key over to "Guard."
(11) Repeat (5) to (10) thus testing the next bank contact on the same level, and

incidentally testing the continuity of the trunking circuit, as a disconnection in the trunking circuit would make the switch "vibrate."

(12) Test in this way at least seven contacts on the switch.

(13) Restore the keys to normal and proceed to test the next switch.

Care must be taken to observe that the selector does not pass a disengaged contact, but takes each in turn if they are available.

In the use of Tester No. 14 (and in other cases also) it is an advantage for the testing officer to face the switch under test continuously. It is found that his attention is distracted by the necessity for finding a particular digit hole in the dial each time, and this can be remedied by inserting a small cork into the appropriate hole of the dial switch. This will enable the testing officer to dial the appropriate digit any number of times by "feel," *i.e.*, without looking at the dial.

DIRECTOR OF INDUSTRIES BENGAL LIBRARY

ection 26

SIEMENS BROTHERS & CO.'S AUTOMATIC TELEPHONE SYSTEM.

This system has been evolved from the Strowger system, and retains many of its important features. Perhaps the principal difference lies in the use of an individual rotary switch associated with each subscriber's line (this the company have used on all their installations). They also separated the relays from the selector mechanism mounting frame from the start.

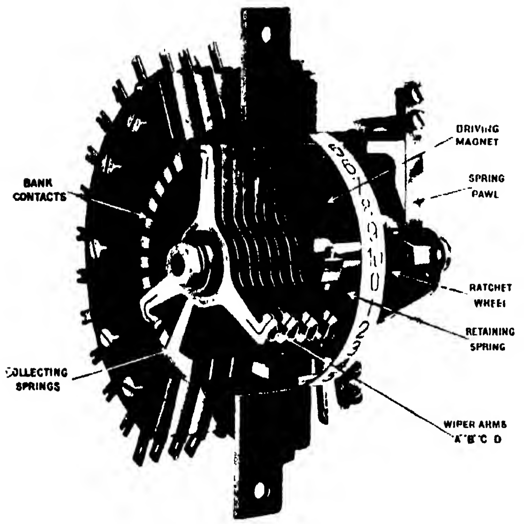


FIG. 65.—SIEMENS PRESELECTOR SWITCH (LEFT-HAND VIEW).

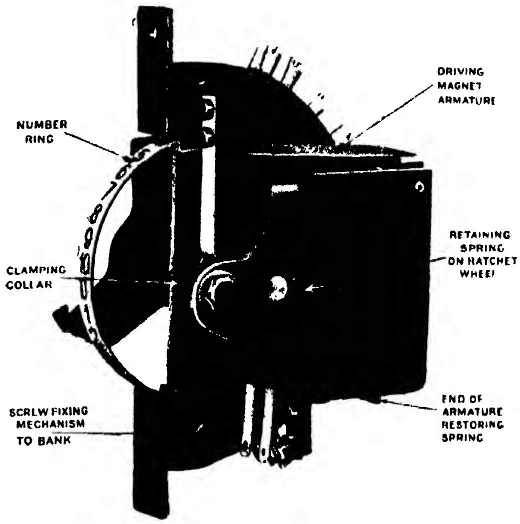


FIG. 66. SIEMENS PRESELECTOR SWITCH (RIGHT-HAND VIEW).

Another distinctive feature is the rotary final selector for selecting an idle line of a plurality to subscribers' offices. Other differences will be noted in the description of the system.

Each subscriber's line is provided with a four-wiper *first preselector* (Figs. 65 and 66), to the multiple contacts of which are connected 10 junction lines, which give access to second preselectors. When not in use for establishing a connection, the arms of the preselector rest on normal contact, and the circuit is then ready to be brought into use for incoming calls. When a call is originated by a subscriber the preselector arms are moved from the normal on to off-normal contacts, and the subscriber's line is then disconnected from the connector multiple, and thereafter tests engaged to incoming calls. When the telephone receiver is replaced, the preselector arms again return to normal, to enable incoming calls to come through to the subscriber's line.

Controlling the preselectors are two relays corresponding to the line and cut-off relays on the common battery manual system.

Meters or registers are associated with the first preselectors, and these are fitted on a special rack, and are cabled to the intermediate distributing frame, where they are jumpered or cross-connected to the various subscribers' lines.

The *second preselectors* are similar to the first, except that as they do not require to return to normal; a fourth arm is not necessary. To the multiple contact banks are connected 10 lines which lead to first selectors or relay repeaters, according to the system used.

The multiple connections of the first and second preselectors are so grouped that a

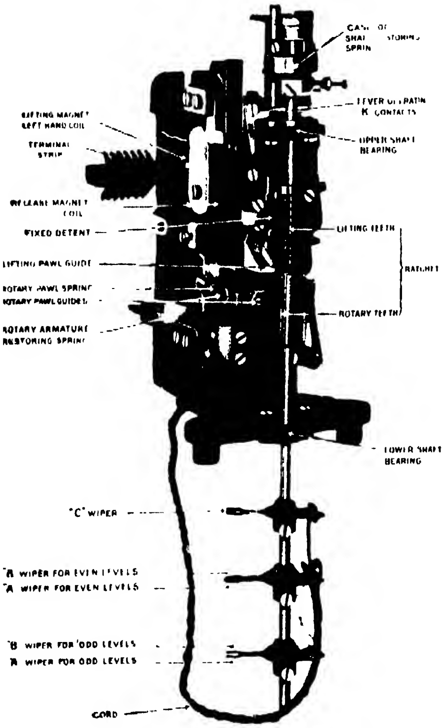


FIG. 67. SIEMENS CONNECTOR SWITCH WITHOUT BANK AND CRADLE.

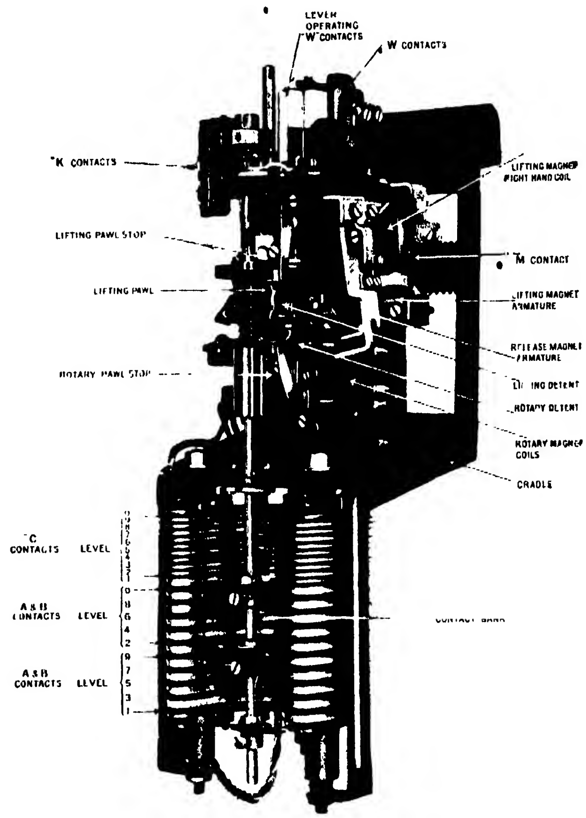


FIG. 68. SIEMENS CONNECTOR SWITCH WITH BANK AND CRADLE.

subscriber has access to any first selector or relay repeater in the particular group to which he is connected, *i.e.*, in a full group to any one of 100.

The preselectors are driven by interrupted current, at a speed of 60 steps per second.

The first and second preselectors and associated apparatus are alike for both full and semi-automatic equipments.

Selectors. The selectors have vertical and rotary motions. The first is under control of the subscriber's dial impulse sender, but the latter is automatic in its action.

The lifting motion raises the wipers to the required level, when circuit changes are effected which switch in the rotary motion, the wipers then being stepped round by interrupted current at a speed of thirty steps per second. Each contact on the level is tested as

the wiper passes over it, until, when an idle line is found, the wipers are brought to rest on that contact.

Selectors and Connectors (Final Selectors). Siemens Brothers were the first to separate the relays from the mechanism mounting and fit them in a small panel adjacent. Fig. 67 shows a perspective view from the left front of the mechanism with the wipers associated with the shaft. Fig. 68 shows a perspective view from the right front of the mechanism with the wipers and banks. This view also shows the method of mounting and fixing the base plate. Fig. 69 shows the relay group associated with each switch.

These switches function on the well-known Strowger principle, but various modifications have been made to render them very reliable. The following are some of the modifications and the advantages claimed.

The lifting and rotary movable detents have been separated for the following reasons:-

To facilitate individual adjustment through the respective ratchet. A locking nut is provided for the adjustment of the vertical detent to obviate the necessity for bending the same.

To allow the shaft to rotate with certainty on the vertical detent, by preventing this detent from being partially withdrawn from the tooth during the rotary movements.

The above construction effectually prevents the possibility of the shaft dropping a level at the commencement of the rotary movement, due to the vertical detent being partially withdrawn when the rotary detent lifts over the first two.

Fig. 69. Siemens Selector Relay Group.

A stop for the lifting pawl on the lifting magnet armature has been added, and this considerably increases the range of ratio of make and break, within which reliable operation of the switch is obtained.

On the banks 11 contacts have been provided in the arc to allow of the last contact being used to stop rotation if the 10 junctions are engaged Busy or other signals can be provided on this contact if desired.

Ebonite is used as the insulation material on the banks because of its non-hydroscopic nature, and because of the accuracy with which it can be manufactured.

Special provision has been made for effectually clamping the banks. This has been

done by introducing another clamping stud at the extreme end of the bank arc. This also, in a measure, protects the wipers from injury.

Mechanically operated contacts assist in the control of the selectors :—

(*a*) The K contacts are fitted on the shaft head and are operated whenever the first vertical step begins. One type of K contact is used throughout the full range of selectors and connectors.

(*b*) The W contacts are controlled from the shaft side and are operated when the first rotary step begins. One type of W contact is used on all selectors.

(*c*) The M contact is controlled from the release magnet armature which, when in the operated position, holds the M contact open. The same type of M contact is used throughout.

The release magnet begins the release, which is completed mechanically.

Each selector is supported in a specially designed cradle which reduces vibration and noise to a minimum.

Connector (Final Selector).—The connector completes the connection for the two final digits of a called number. Each connector gives access to 100 subscribers' lines.

Ringing, busy, free and lamp-flashing signals are controlled from the connector.

The connector switches are practically identical with the selectors in construction, and also have vertical and rotary motions, both of which are under the control of the dial.

The lifting motion raises the wipers to the required level, *i.e.*, selects the particular tens group. Circuit changes are then effected which switch in the rotary motion, and the last set of impulses steps the wipers round to the contact of the desired number

If the desired line is idle, ringing current is sent out and a free signal is given to the calling subscriber, but if engaged busy tone is given.

Mechanically operated contacts assist in the control of the connector, as before described for the selector.

The release magnet begins the release, which is completed mechanically.

Each connector, like the selector, is supported on a specially designed cradle, which reduces vibration and noise to a minimum.

In the diagrams the automatic switches and relay contacts are shown in their normal or resting position.

Section 27

CIRCUITS OF A FOUR-DIGIT SIEMENS SYSTEM (Figs. 72 to 76)

The circuits on a through connection, engaging a line switch, preselector, first and second selectors and a connector, are as follows. The circuits are numbered in the order of operation.

1. When a receiver (Fig. 72) is lifted to initiate a call relay R′ energises.

2. Circuit through driving magnet M2(D1). The line switch wipers are moved round at 60 steps per second. The wipers move off the normal contacts, thereby disconnecting the test wire C from the connector multiple banks, and so engaging the calling line against incoming calls.

3. When an idle line is found relay R3(T') energises in series with relay RR3(R2). Relay R' is cut off. Relay R3 opens driving circuit 2 so that the wipers come to rest on the idle line contacts.

3'. Circuit 3 is completed over 3' so that the resistance of relay R3 is about 15 ohms. If now another preselector, hunting for another idle line, touches the multiple contact of this busy line the calling test relay being shunted by this 15-ohm winding will not operate, and the wipers move to the next contact.

4. The loop 1 is now extended to the preselector (Fig. 73). This preselector does not return to normal when released.

5. Relay RR3 energising completes circuit 5 over the contact on which the wiper last came to rest and, if idle, that line will again be taken into use.

5'. Circuit 5 is joined to 3 through the 10-ohm winding of relay R5(T2), and relay RR3 cut off. Magnet M2 is also cut off.

6. If the line found connected is busy the driving circuit is completed, and magnet M6(D2) rotates the associated wipers until an idle line is found to the preselector.

7. The loop 1 and 4 is then extended to the first selector and relay R7(A) energises.

8. The lamp L glows to indicate that the switch is in use. It is also found valuable in traffic observations.

9. Short circuit for 600-ohm coil of relay R5(T2).

The test circuit from the preselector is completed through circuit 5 and 5", in parallel at the first selector. The 250 ohm resistance on relay R12(V^2) is wound inductively, but the number of turns is such that it cannot operate or hold the relay. It does, however, improve the speed of operation and the time lag of release. Relay RR5(C) energises, but plays no part in building up the connection.

10. Relay R7(A) completes a circuit for relay R10(V^1), which energises and cuts relay R56 from the B line and connects the retardation coil RC in its place.

11. Relay R10(V^1) opens the circuit to the group relay and completes a circuit to glow lamp L'.

First Digit Impulses (Fig. 74). On the first break relay R7(A) de-energises and opens circuit 10, but relay R10(V^1) is slow to de-energise.

12. Relay R12(V^2) energises, is also slow to de-energise, and remains energised during each train of impulses.

On completion of the first impulse relay R7(A) re-energises.

13. The shaft is raised one step and the K contacts are operated. K' opens circuit 5 to relay R12. K" opens circuit 11 and lamp L" ceases to glow. The magnet M13(H) now responds to the remaining impulses of the train to lift the wipers to the required level. When the dial returns to normal relay R7 is held energised over the loop. Circuit 12 is now open and relay R12 de-energises. Circuit 13 to lifting magnet M13 is now open.

14. The driving magnet M14(D) is energised through the interrupter, and the shaft and wipers are rotated. At the first step the W contacts are opened. Circuit 13 is opened at W'.

15. Holding circuit for relay RR5(C) is prepared.

The W" contact is opened to throw relay R10(V^1) under the control of relay R7(A) for release.

16. When the C wiper finds an idle line, battery from the next switch energises relays RR5(C) and R16(A) (Fig. 75). Circuit 15 is then effective. Circuit 14 is opened to stop the driving magnet and bring the wipers to rest on the contacts of the selected line.

17. The C wiper (circuit 16) is connected directly to earth over the shaft contact K', to engage the called line, and relay R17(C) energises.

18. The loop 7 is extended to the second selector.

19. Circuit for bridge coil M19(RC) over relay R16(A); one winding only of the former is effective now.

Second Digit Impulses (Fig. 75).

20. At the first break of the loop circuit relay R7(A) de-energises and relay R12(V²) energises. Battery is connected to line through the 50-ohms resistance, in parallel with the 500-ohms coil of the retardation coil RC, to cut out self induction from the impulse circuit, and to increase the current to line. After each train of impulses relay R12(V²) de-energises.

21. Relay R21(B) energises on first break.

22. The 400-ohm winding of relay R21 is short circuited to make this relay slow to release during the impulsing.

23. New impulse circuit for relay R21, when K' operates at the first step.

24. Relay R16(A) re energises and the lifting magnet M24(H) is energised to lift the shaft and open the K contacts.

After the impulses relay R16(A) remains energised. Circuit 23 is open and relay R21(B) releases.

25. The driving magnet M25(D), through the interrupter, rotates the shaft. At the first step the W contacts are opened. Contact W2 opens the circuit of magnet M24(H).

26. Contact W' places relay R17(C) under the control of relay R21.

27. When an idle line is found, relay R21(B) energises by its 400-ohm coil.

Circuit 25 is opened to cut off magnet M25(D) to bring the wipers to rest on the contacts of the selected line. Relay R27(V¹) (Fig. 76) is energised. Contact 26 is opened and relay R17(C) releases. Relay R16(A) releases. Circuit 27 through the 400-ohm coil is open.

28. Holding circuit of relay R21(B).

29. The wiper 27' is connected directly to earth to engage the line.

30. Loop 18 is extended to connector (or third selector).

31. Relay R31(A) is energised by current from the previous selector.

32. Relay R32(F) is connected to the B wire for calls from a manual board, and is not operated at this time on an automatic system. The circuit is earthed at both ends.

33. Relay R33(Y¹) is energised.

34. Relay R34(C) is energised over the C wire.

35. Relay R34 is dependent on the calling subscriber over the C wire.

36. Parallel path to earth for relay R31(A).

Impulses for Tens Digit on Connector (Fig. 76).—Relay R31(A) de-energises on first break.

37. Relay R37(V²) energises, remaining energised during the train of impulses.

38. Parallel path for relay R33(Y¹) to hold it energised when contact K' opened.

39. Relay R31(A) re-energising steps the shaft up one level by M39, and the K contacts are opened. The further impulses step the wipers to the desired level. After the last impulse relay R31 remains energised. Circuit 37 is opened, and relay R37(V²) de-energises. Relay R37 opens circuit 38, and relay R33 de-energises. Relay R33 is not energised on rotary impulses. Relay R33(Y¹) opens circuit 39, to cut off magnet M39(H), and closes a circuit for the rotary magnet.

Impulses for the Units Digit.—Relay R31(A) de-energises on the first break. R37(V^2) energises as before. Relay R31 re-energises at the end of the first impulse.

40. The rotary magnet M40(D) is energised (part of circuit over 39).

The W contact is operated at the first step.

41. New circuit for relay R27(V^1).

The further impulses step the wipers round to the desired line. An engaged line cannot be interfered with, because the line and test circuits to the wipers are opened at 30′, 30″, 30‴.

42. After the impulses relay R31(A) remains energised over circuit 30—31.

Relay R37(V^2) de-energises, because relay R31(A) opens circuit 37. Circuits 39 and 41 open, and relay R27(V^1) and magnet M40(D) are cut off. Circuits 31 and 36 are open, and relay R31(A) de-energises.

Between the de-energisation of relays R37(V^2) and R27(V^1), the line called is tested.

43. If the called line is idle relay R43(P) is energised over the called subscriber's cut-off relay RR43 (corresponding to circuit 43, marked on the calling subscriber's line, Fig. 72).

44. The line called is engaged through the 30-ohm winding of relay R43. The line contacts 30′ and 30″ are closed.

45. Ringing circuit. Contact 45′ ensures that relay R37 shall be fully released before relay R45(TR) energises.

When the called subscriber replies relay R45 energises. The short-circuit 47 is then opened, and the 1,000-ohm winding of relay R45 is in series with relay R31, which holds until the release of the connection.

Relay R45 energising cuts off the ringing and joins the A and B lines through to the connector.

46. Circuit to blocking alarm signal, which is only used on a single release system.

48. Battery feeding relay R33 is connected to the called subscriber's line. Relay R31 again energises over 31—36, to connect to the calling side of the A wire.

49. Relay R37 energises.

50. The calling side of the B wire is connected to the second winding of relay R31. Metering battery also connected. Relay R34 is energised, and is under the control of the calling subscriber, to guard the release of the connection. Relay R37 is energised to provide for the registration of the call.

If the line called is busy, that C line is connected through the 30-ohm coil of its relay R43 (corresponding to the circuit 44). When, therefore, relay R37 de-energises and connects another R43 on the same C line, the latter relay (930 ohms) is shunted by the 30 ohms already on the line, and does not receive sufficient current to energise it.

51. Intermittent busy tone is now given to the calling party through relay R33 by induction, and a circuit for lamp flashing completed.

When a Call is from a Line on a Manual Board. The relays and condensers are cut out of circuit, and the speaking current is fed from the cord circuits. Prior to the dialling of the tens digit the conditions are similar, except that battery is connected to the B wire from the operator's position. Relay R27 is then energised. R32 energises in circuit 32.

52. Relay R 32 cuts circuit 36 from earth, and changes it over to resistance, battery and earth, but R31 remains energised over circuit 31.

53. Relay R32 cuts off condensers, and joins A and B wires through, and opens circuit 48 to disconnect relay R33. One winding, however, is still connected to the B wire by 48′ at relay R45.

55. Holding circuit of relay R32, which remains energised until the connection is released.

The operator now dials the number required, and the connector operates as before described. When the called party answers relay R45 energises and connects the A and B wires through, and opens contact 48′, so that relay R33 de-energises. Circuits 31 and 50 are open, and relay R31 de-energises. Battery feeding is from the cords, where also the usual supervisory signals are fitted.

If on this manual call the called party is busy, relay R33 is intermittently energised (circuit 51), and circuit 52–36–31 is completed to the supervisory relay of the cord circuit. Busy tone is also received over circuit 48 to the B wire.

Release on an Automatic Connection.—When the calling receiver is replaced circuit 7 is opened, and relay R7 de-energises. Circuit 12 is closed, and relay R12 energises. Circuits 5 and 15 are connected at relay R12 to earth relay RR5, in connection with the registration of the call. Circuit 10 is opened and relay R10 de-energises.

56. When relay R10 de-energises, relay R56 is connected to the B wire, and is energised by current from relay R31.

57. Battery is connected through 50 plus 40 ohm resistances to the C wire, to energise the subscriber's meter, MR57.

Circuit 12 then opens and relay R12 de-energises. Circuit 5–15 is opened, and relay RR5 de-energises.

58. The release magnet M58 (Fig. 74) energises, and the shaft and contacts K and W return to normal. Contact K2 then opens release magnet M58 circuit. Circuit 5 is opened and relays R5 and R3 de-energise to release the pre-selectors. Relay R3 connects up the subscriber's line relay R′.

59. Circuit 2 is again closed and the wipers are returned to normal. This circuit is opened when wiper 59′ returns to normal.

Relay R5 de-energises slowly, because of the short-circuited winding.

Circuit 8 is opened and the lamp L ceases to glow. The driving circuit is again completed. A and B wires are opened. Circuit 5′ is opened, and relay RR3 is again connected in circuit 3.

Circuit 28 is opened and relay R21 de-energises.

60. The release magnet M60 (Fig. 75) energises, and the shaft and K and W contacts return to normal. Contact K′ then opens the circuit of the release magnet. Circuit 16 is completed for relay R16.

Circuit 27 is opened, and relay R34 de-energises. Circuit 44 is opened and relay R43 de-energises. The ringing circuit 45 is open.

61. The release magnet M61 energises and shaft and K and W contacts return to normal. The release magnet circuit is opened.

On the manual board the release is under the control of the operator. When the C wire is opened, relay R31 de-energises and the operations are as before.

Section 28

DISCRIMINATOR SYSTEM OF PRIVATE BRANCH CONNECTORS (Fig. 79)

A study, by Siemens Brothers, of the requirements to be met in providing an efficient system for dealing with private branch exchange traffic led to the development of an entirely new system, in which the ordinary form of connector is replaced by automatic switches similar in construction to pre-selectors, but provided with 25 contacts in the bank instead of 10. These switches they have designated *discriminators*.

Two such switches may be used on each P.B.X. connector, and the circuit arrangements are such that only one switch is brought into use on a call. Each switch has five wipers, four sets of contacts, and one normal and off-normal contact.

If four lines, or four sets of contacts, be reserved for each P.B.X. exchange number, then each discriminator can accommodate five P.B.X. groups, which leaves five spare contacts that can be utilised for providing an additional line, or lines, for any of the groups.

Each private branch exchange has only one exchange number, and when that number is called the discriminator seeks out an idle line in the group.

Two wipers in series form the testing circuit, and the contacts brushed over by one of the wipers are coupled together, to form five groups of four lines each.

A standard pre-selector, termed a *digit switch*, is used to take the units impulses from the subscribers' dials, the wipers being stepped round a number of contacts corresponding to the number called. The 10 contacts of the digit switch are wired to the testing circuits of the 10 groups of lines on the two discriminators, the whole forming one P.B.X. connector. When the digit switch wiper comes to rest on the selected contact, the testing circuit of only one group is connected up, and the lines on the other groups test engaged to a discriminator, when searching for an idle line in a required group.

The P.B.X. connectors are thus divided into *tens* instead of *hundreds* groups, and where necessary an extra rank of selectors is fitted to select the tens group.

The discriminator and digit switches in the circuit shown in Fig. 79 are driven at a speed of 30 steps per second.

The P.B.X. Discriminator Circuit (Fig. 79).—The circuit of the B.P.X. connector resembles that of the ordinary connector.

An idle connector circuit is selected in the usual way, and the subscriber dials the units impulses.

The digit switch is stepped round, and couples up the driving circuit of the required discriminator, and, at the same time, connects up the testing circuit of the required P.B.X.

The wipers of a discriminator are brought to rest on an idle line, ringing current is applied, and the line engaged.

If all the lines on the P.B.X. are engaged, the discriminator steps round to the last contact of the bank, where it stops and sends busy tone and lamp-flashing signals towards the caller.

The circuits are numbered in the order of operation, and are as follows :—

1. When a P.B.X. connector is taken into use, relay R′ is energised over the third wiper of the digit switch, which is on the normal contact, and over the C wire.

2. Earth is connected to one coil of relay R2, which is energised over the A wire to the first selector or relay repeater.

3. Relay R3 is connected to the B wire, but is not energised on automatic calls, because the B wire is connected to earth at the first selector, or relay repeater.

4. Relay R4 is energised over the C wire, to earth at the selector.

5. Holding circuit for relay R4 which is now dependent upon the calling subscriber for release.

The circuit is now ready to receive impulses.

The subscriber now dials the units digit of the required number, and the dial returns to normal, the line being interrupted a number of times corresponding to the value of the number called.

6. At the first interruption, relay R2 de-energises, and relay R6 energises. The latter is slow to release, and remains energised during the train of impulses.

7. On the completion of the first impulse, relay R2 is again energised, and the digit switch driving magnet M7 receives an impulse. Further impulses of the train are now directed to the digit switch magnet M7 by relay R2 contact, and the wipers are moved round a number of steps.

When the wipers move from the normal to the off normal contacts the following circuit changes are brought about

Wiper No 2 prepares the driving magnet circuit of the discriminator to be brought into use to complete the connection.

Wiper 3 disconnects the relay R′ from the selector C wire, and places it under the control of relay R6.

Wiper 4 prepares the digit switch driving magnet M7 for release conditions.

Wiper 1 connects up the testing circuit of the required P B X group. The testing circuit of other groups on the discriminator are disconnected and therefore engaged.

On the completion of the train of impulses relay R2 is held energised and, as circuit 6 is held open, relay R6 releases.

Relay R6 de energising opens circuit 7 of the digit switch driving magnet M7.

8. Circuit 8 is open and relay R′ is released.

Relay R′ opens circuit 2, and disconnects relay R2 from the A wire.

9. Relay R′ de-energising completes the circuit of the driving magnet M9 of the discriminator Magnet M9 is operated and rotates the wipers of the discriminator.

10. The wipers X^1 and X^2 are now rotated until an idle line is found in the group on which wiper 1 of the digit switch has been set, when relay R10 is energised through the cut-off relay on the wanted subscriber's preselector and earth

11. Relay R10 closes a holding circuit for itself, through its 30-ohm coil, at the same time engaging the selected line to other searching discriminators.

12. Relay R10 A and B wire contacts (which are open during the searching to prevent interference on engaged lines), now close, and ringing current is connected to the called line.

Relay R10 opens circuit 9, so disconnecting the discriminator driving magnet, and bringing the wipers to rest on the called line.

When the called subscriber answers, relay R12 is energised.

Relay R12 removes the short-circuit from its second coil, which is now held operated in series with relay R4, over circuit 4.

13. Relay R12 connects through the A and B wires, and opens the ringing circuit 12. Relay R13 is now energised over the loop.

14. Relay R2 is now energised from battery on the selector A wire.

15. Relay R6 is energised.

16. Relay R6 energising connects the second coil of relay R2 to the B wire, in readiness for the registration of the call.

The speaking circuit is now completed, and is balanced by the coils of relays R2 and R13 on opposite sides of the condensers.

If all lines in the wanted P.B.X. group are engaged :

17. The discriminator hunts for an idle line in the manner just described, but all are engaged. The lines engaged on originating calls have their testing circuits disconnected on the C arms of the first preselectors, those engaged on incoming calls are engaged by the 30-ohm coil of the relays R10 holding the lines, and the discriminator passes over all lines in the group until the last contact of the bank is reached, when relays R10 and R′ are energised.

Relay R10 after energising is held through its 30-ohm coil (circuit 11).

The ringing circuit is not completed, as the A and B wires on the last bank contacts of the discriminator are not used.

Relay R10 opens the circuit of the discriminator driving magnet.

18. Busy and lamp-flashing circuit.

Relay R13 is intermittently energised but is not required at this time. The busy tone is induced in the line coils of relay R13, and transmitted over the condensers to the caller. The caller on hearing the busy tone replaces his receiver, and the connection is released.

When a Call is made from a Manual Switchboard. When a call is set up from a manual board, or from an incoming junction position, circuit changes are automatically effected, by which the condensers and line relays on the P.B.X. connector are cut out of circuit. The subscriber is then directly connected to and the speaking current is fed from the cord circuit on the manual board or from the incoming junction position.

The first part of the setting up of the connection is the same as already outlined, except that, in this case, battery is connected to the B wire at the operator's position.

When, therefore, circuit 3 is completed, as already described, relay R3 is energised, from battery, over the B wire.

19. Relay R3 energising disconnects the A and B wires from the condensers, and connects the wires through, so as to give a clean metallic circuit for supervisory signals, and for feeding current.

20. A second winding of relay R3 is connected to the C wire, so that relay R3 is held until the release of the connection

Contact 13′ opens to disconnect the relay R13 from the A and B wires. One coil of relay R13 still remains connected to the B wire, through relay R12, contact 13″.

The operator dials the units digit of the number of the required group, and the connector is set on an idle line in the group, as already described.

When the wanted subscriber replies, the tripping relay R12 is energised, connects the A and B wires through, and disconnects relay R13 from the B wire at 13″. Since relay R13 is now disconnected, the circuit of relay R′ remains open at 14′ contact. Relay R′ is thus disconnected from the A wire at 14′ contact, and from the B wire at 16′ contact.

The called subscriber is supplied with microphone current direct from the manual board, and controls a supervisory signal on the position, in accordance with standard manual practice.

A Call made from a Manual Board when all the Lines in the wanted P.B.X.

Group are engaged. The setting up of the connector is as has been already described, but, since all the lines in the group are engaged, the relay R10 cannot be energised to cut the driving circuit of the discriminator. The discriminator, therefore, rotates until the wipers reach the last contact, whereupon relay R10 and relay R′ are energised, and effect circuit changes as already described.

21. The relay R13 connects battery, intermittently, over the A wire to the operator's position.

Busy tone is also transmitted to the operator since the relay R13 is connected to the B wire, through 13″ contact of relay R12.

On receiving the lamp-flashing signal the operator withdraws the plug, and thereby releases the connection.

Release of the Connection when the Automatic Calling Subscriber replaces the Receiver. By replacing the receiver, the calling subscriber sets up the release conditions at the first selector, or relay repeater. Battery is connected to the B wire of the P.B.X. connector, over the relay R2, so that the call is registered as the release proceeds.

The release is given along the C wire, through the various selectors in use, and finally, the C wire leading to the P.B.X. connector is opened, whereupon relays R4 and R12 are released; relay R12 is however slow to release. Relay R2 is also released by the opening of the A wire at the first selector.

Holding circuit 5 of relay R4 is opened.

Circuit 15 is open and relay R5 de-energises.

Circuit 17 is open and relay R10 de-energises.

Circuit 12 opens the ringing circuit from the B wire.

Relay R2 is slow to de-energise, and 16′ contact remains closed while the call is being registered.

When relay R10 releases contacts 12′ open to prevent engaged lines being disturbed while the discriminator wipers are returning to normal

22. Circuit of the discriminator driving magnet M9.

The discriminator wipers rotate, and are brought to rest on the normal contact, because the driving circuit is cut as soon as the normal contact is reached.

23 The digit switch driving magnet M7 circuit is now completed, through the discriminator wipers on normal contact, digit switch, No. 4 wiper, magnet M7 and earth.

The digit switch wipers rotate until the driving circuit is opened by the No. 4 wiper, thus bringing the wipers to rest on the normal contact.

The apparatus is now at normal and ready to be brought into use on another call.

Release when the called subscriber replaces the receiver can be provided when required.

Release of a Connection made through a Manual Board. On these calls the release of the connection is under control of the operator, as the called subscriber has no direct connection with the connector-switch relays, after the connection is set up.

The release is given by the operator interrupting the C wire. The disconnection is given along the C wire, through the various selectors in use, and, finally, the C wire leading to the P.B.X. connector is opened, when relays R4, R12 and R3 release.

The circuit is now in the same condition as when the calling subscriber, on a straight automatic connection, hangs up first, and the release of the switches is effected as already described.

Section 29

FAULT AND GROUP ALARM SIGNALLING ON THE SIEMENS SYSTEM

Circuit operation of fault and group alarm signalling on the first and second preselector racks (Figs. 70, 71).

When the Rack Main Fuse Melts.—If the main fuse F (Fig. 71), protecting the rack, melts the relay R65 is energised, either through the fault, or by the next circuit brought into use.

65. The circuit is completed over 65 to fuse bar, then through the faulty circuit to earth.
66. Locking circuit of relay R65 until fault receives attention.
67. Alarm lamp L glows to indicate the particular circuit affected.
68. Lamp L2 glows to indicate on which rack the fault exists, and relay R68 energises.
69. The section lamp glows.
70. The alarm buzzer resounds.

When the fuse is replaced relay R65 is short-circuited, to restore all circuits and apparatus to normal.

When a Branch Fuse Melts.—These fuses are of standard type (see Fig. 77).

71. When a fuse melts relay R71 is brought into circuit, either from the battery directly or through the motor interrupter, according to which particular circuit is affected.
72. The associated lamp L′ glows.
73. Relay R68 energises, as before, to close circuits 69 and 70.

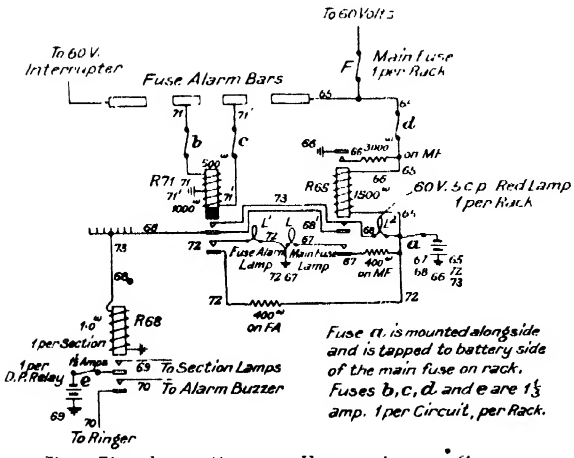


FIG. 70.—LINE SWITCH FAULT ALARM CIRCUITS (SIEMENS).

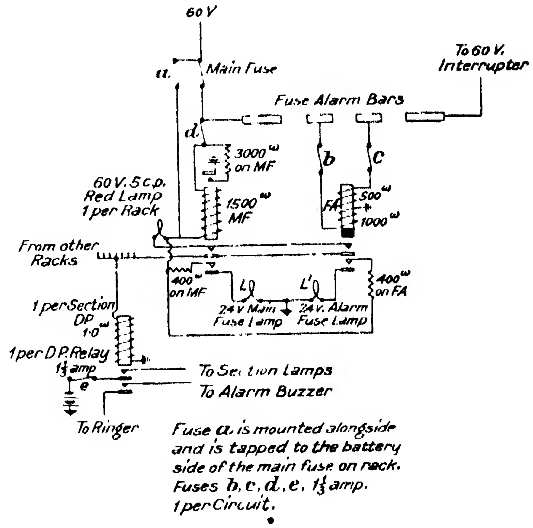


FIG. 71.—2ND PRESELECTORS FAULT ALARM CIRCUITS (SIEMENS).

P.G. (Permanent Glow) Faults.—These are quickly localised back, from the first selector to the first preselector, by connecting a tone to the C line to the first selector. The rack on which the faulty line terminates can then be quickly found, and, thereafter, the faulty line.

A low resistance retardation coil is fitted at each rack, and the holding circuits (3') of all the relays R3 on the rack are taken through the retardation coil to earth.

A branch from each retardation coil is wired to strips of jacks, one jack per rack, in a position convenient to the Test Clerk.

The tone connected to the faulty line at the first selector can therefore be found quickly by tapping with a receiver along the strips of jacks until, when one is found, the jack to which it is connected indicates the number of the first preselector rack on which the faulty line terminates.

A similar test is applied to the C line on the terminal strips on the racks. The relays R3 now act as retardation coils. The terminal on which tone is found indicates the number of the preselector. The test clerk can then have the line connected to a plugging-up circuit.

Group Control (Figs. 72, 73).

74. Relay R74 is normally held short-circuited by the contacts of the relays on the second preselector to which a particular row of first preselectors has access. When all the outgoing circuits from the row of first selectors are simultaneously engaged, the short-circuit is removed, and relay R74 energises.

The preselector motor driving circuit 2 is opened, of the row of first preselectors, to prevent switches running should other subscribers attempt to call. The preselectors do not operate whilst all the outgoing junctions are busy. Circuit 6 is not closed, therefore the second preselector magnet is cut off.

75. Tone is connected to the transformer TC and induced in circuit 1. A subscriber in those conditions receives the busy signal.

76. Circuit of group lamp, to notify the traffic observation clerk that the lines of that group are all busy.

When a second preselector becomes free the short circuit is removed, relay R74 de-energises, and working begins again.

Second Preselector Racks. The fuse alarm circuits (Fig. 71) are identical to those on the first preselector racks, and the operating is, therefore, exactly as already described.

Group Control Circuit (Figs. 72, 73).—A row of first preselectors has access to a column of 10 second preselectors, each of these second preselectors being on a different row.

As soon as all the second preselectors in one column are engaged, the driving circuit of the row of first preselectors having access to that particular column is cut and busy tone is connected to the line relays.

The second preselectors are arranged in 10 rows of 20 switches per row, and each row has access to a panel of first selectors.

It is evident, therefore, that as 20 second preselectors have access to only 10 first selectors, it becomes necessary, as soon as the 10 selectors are all engaged, to prevent the other 10 idle second preselectors from being brought into use, *i.e.*, that contacts on the first preselectors giving access to these idle second preselectors must be made busy.

Further, the group controls of the columns of the idle 10 second preselectors must also be cut, in order that, should the other switches in any column be brought into use, the group relay on that column will be energised, cut the driving circuit on the row of first preselectors, and connect busy tone to the line relays.

The driving circuit on a row of first preselectors is therefore cut, and busy tone connected to the line relays, if and when :--

(*a*) The 10 second preselectors, to which the row has access, are simultaneously engaged.

(*b*) Only some of the second preselectors are in use, but the outgoing lines on the idle switches are all engaged.

Circuit Operation.—The relay R74, controlling a row of first preselectors, is under the control of the relays on the 10 second preselectors, to which the first preselectors have access.

Immediately a second preselector is taken into use, the group control circuit 76 on that preselector is cut, by the relay RR3 contact, and when a free line is found relay R5 contact takes the place of relay RR3, which de energises.

As soon as the 10 second preselectors in the columns are all engaged, the relay R5 contacts are all open, the short circuit is removed from the relay R74, which operates, cuts the driving circuit of the first preselector, connects busy tone to the line relays, and closes the circuit of the group lamp (see circuits 74 -76).

The group control circuit on each of the 20 second preselectors in the row requires to be cut, and the battery circuit feeding the RR3 relays has also to be disconnected. Associated with the group relay on the panel of first selectors, therefore, are four auxiliary relays (R78), which are fitted on the second preselector racks.

When the 10 first selectors are all engaged, the group relay R79 is energised, and it in turn closes the circuit 78 of the R78 relays.

The relays R78 contacts open the group circuits, on the 20 second preselectors, and at the same time disconnect the battery lead for the RR3 relays, thus engaging that contact on the first preselectors which gives access to the row of second preselectors, the outgoing lines of which are all engaged

As soon as a first selector becomes idle, the group relay R79 and the R78 relays de-energise, restore the second preselector circuits to normal, thereby opening them up again for further use.

On each second preselector a cut-out key COK is provided, to enable the switch to be engaged, when a maintenance official is working on the circuit. When this key is pulled out the C line is disconnected, and the control circuit across the group relay is also cut. A lamp, common to the rack, is associated with the cut-out keys, and serves to draw attention to the fact that one or more switches are cut out of circuit.

Section 30

ALARM SIGNALS ON THE SELECTORS

First Selector (Fig. 74).—On the first selector racks alarm signals are provided for the following faults :—

(*a*) Main fuse on rack melts.
(*b*) Branch fuse melts.
(*c*) Shaft sticks on release.
(*d*) Subscriber's line is P.G.

Alarms (*c*) and (*d*) are under the control of a time-lag device. A group signal is provided to show when all the 10 selectors on one panel are simultaneously engaged.

The second and subsequent selectors are provided with alarms (*a*), (*b*) and (*c*), and the last is under the control of a time-lag device.

First Selector (Fig. 74)—**Rack Main Fuse Melts.**

87. When the main fuse melts relay R87 energises, either through the fault or by the next circuit brought into use.

88. Relay R87 closes a holding circuit for itself.

89. Relay R87 closes the circuit for the alarm lamp L89 associated with the main fuse, so indicating which particular circuit is affected.

90. Relay R87 closes the circuit of the 5 c p. rack alarm lamp, L84, and the relay R84. The rack lamp indicates which particular rack is affected, and relay R84 closes the section lamp and alarm buzzer circuits, as previously described.

When the fuse is replaced relay R84 is short-circuited, releases and restores the alarm circuits to normal.

Branch Fuse Melts.—These fuses are of the standard Post Office type (Fig. 77).

91. When a fuse melts relay R91 energises, either from a battery circuit, or through the motor interrupter, according to the particular circuit affected.

92. Relay R91 closes the circuit for the rack lamp L84 and relay R84, and the section alarm lamp glows, and also closes the circuit of the alarm buzzer, as before described.

93. Relay R91 closes the circuit of the lamp L93 on the rack associated with the branch fuse alarm.

The replacing of the melted fuse restores the alarm circuits to normal.

Shaft Sticking on Release.—When the release magnet is energised it is held under current until the shaft falls, when the circuit is broken by the opening of the key K contact.

58. In series with the release magnet is a relay RR58, which is energised and held, so long as the release circuit is closed. Relay RR58 only prepares the alarm circuit, which is under the control of the time-lag device, and only after a predetermined interval is the alarm sounded.

81. Relay RR58 connects relay R81 to the starting contact on the slow speed cam, and at the beginning of a revolution relay R81 is energised.

82. Relay R81 when energised disconnects itself from the line to the slow-speed cam and locks up. Relay R81 is now under the control of the relay RR58 and, should the release magnet circuit be interrupted by the shaft reaching the normal position, relay RR58 and relay R81 are released, without the alarm being sounded

83. A circuit for relay R83 is prepared, and if the faulty conditions are maintained throughout the revolution of the slow-speed cam, relay R83 is energised by the closing of the alarm contact, and locks itself.

84. Relay R83 closes a circuit for the rack lamp L84 and relay R84. Relay R84 closes the circuit for the section lamp, and starts the alarm buzzer, as before described.

The fault is now localised by :

(*a*) Section lamp.
(*b*) Rack lamp.
(*c*) Lamp associated with shaft sticking alarm.
(*d*) An inspection of the selectors on the panel.

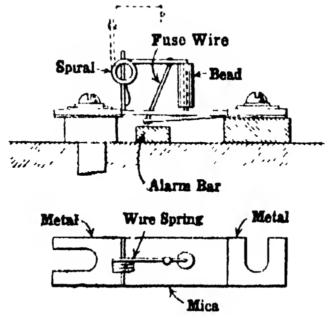


FIG. 77.- ALARM FUSE.

The faulty selector release magnet will be in the operated position.

When the selector shaft is released the alarm apparatus will return to normal.

P. G. Faults. If a subscriber's line develops a fault, or a receiver is left off the switch-hook, a first selector is taken into use by the preselectors, the relay R7 on the selector is energised through the fault, and brings into circuit the relay R10, which is also energised.

11. Relay RR11 is energised, and the lamp associated with the selector glows.

85. Relay RR11 completes the circuit of the lamp on the rack associated with the P.G. alarm circuit.

86. Relay RR11 couples up relay R81 to the starting wire of the slow-speed alarm circuit. The operation of the circuit is now exactly as already described in 81 83.

When the alarm buzzer is sounded, the maintenance official localises the fault to the selector on which the P.G. lamp L11 is glowing.

A plug, to which is connected a battery from a tone coil, is inserted into the jack associated with the selector on the rack, and the faulty line is quickly localised on the first preselector racks, as described in connection with the first preselector. As soon as the tone plug is inserted into the selector jack, the selector shaft is raised a step or two by hand, thereby restoring the alarm apparatus to normal.

Group Control Circuits.—A group relay is fitted on each panel of ten first selectors, to control the first and second preselectors, and to show when all the selectors are simultaneously engaged.

80. The relay R79 is normally short-circuited by the line 80, and K2 contacts in each relay set on the panel.

When the selectors are all engaged all the lines 80 are open, and relay R79 then energises in circuit 79.

81. Relay R79 closes the circuit of the lamp on the traffic observation position.

78. Relay R79 closes the circuit of the relay R78 on the second preselector racks.

As soon as a selector becomes free relay R10 is released and the K contact resumes normal. Relay R79 is short-circuited and releases, so releasing the relays R78. The circuits are then at normal.

Second and Subsequent Selectors (Fig. 75). Alarm signals are provided on the following circuits :–

(*a*) Main fuse melts
(*b*) Branch fuse melts.
(*c*) Shaft sticking on release.

The relays and the circuits are arranged exactly as on the first selector diagram, so that the operation of the circuits is exactly as already described for the first selector.

Group control circuits :—

These are not provided on the second and subsequent selector racks.

Section 31

ALARM SIGNALS ON THE CONNECTORS (Fig. 76)

On the connector racks alarm signals are provided for the following faults :—

(*a*) Main fuse on rack melts.
(*b*) Branch fuse melts.
(*c*) Shaft sticking on release
(*d*) Blocking signal alarm for use on single release working.

Alarms (*c*) and (*d*) are under the control of the time-lag device.

A group alarm signal is provided to indicate when all the connectors on one panel are simultaneously engaged

Rack Main Fuse Melts.

94. When the main fuse melts the relay R94 is energised, either through the fault or by the next circuit brought into use.

95. Relay R94 closes a holding circuit for itself.

96. Relay R94 closes the circuit of the alarm lamp MFL96, associated with the main fuse, so indicating which particular circuit is affected.

97. Relay R94 closes the circuit of the 5 c.p. rack alarm lamp L97, and the relay R97 energises. The rack lamp indicates which particular rack is affected, and relay R94 closes the circuits for the section lamp and alarm buzzer, as previously described.

When the fuse is replaced relay R94 is short-circuited, releases, and restores the alarm circuits to normal.

Branch Fuse Melts. These fuses are of the Post Office standard type.

98. When a fuse melts relay R98 is energised directly from the battery.

99. Relay R98 closes the circuit for the rack lamp L97 and relay R97, so glowing the section alarm lamps and sounding the alarm buzzer.

100. Relay R97 closes the circuit of the lamp on the rack associated with the branch fuse alarm.

The replacing of the melted fuse restores the alarm circuits to normal.

Shaft Sticking on Release.—When the release magnet is energised, it is held under current until the shaft falls, when the circuit is broken by the opening of the K contact.

61. In series with the release magnet is a relay R61, which is energised and held so long as the release circuit is closed. Relay R61 only prepares the alarm circuit, which is under the control of the time lag device, and only after a predetermined interval is the alarm sounded.

101. Relay R61 closes the circuit for relay R101, to the starting contact on the slow speed cam, and at the beginning of a revolution relay R101 is energised.

102. Relay R101 locking circuit.

Relay R101 is now under control of relay R61, and should the release magnet circuit be interrupted by the shaft reaching normal position relays R61 and R101 are de energised without the alarm being sounded.

103. Relay R101 prepares the circuit of relay R103.

If the faulty conditions are maintained throughout the revolution of the slow speed cam, relay R103 energises, by the closing of the alarm contact and locks itself.

Relay R103 closes the circuit for the rack lamp L97 and relay R97. Relay R97 closes the circuit of the section lamps and starts the alarm buzzer.

The fault is now localised by:

(*a*) Section lamp
(*b*) Rack lamp.
(*c*) Lamp associated with shaft sticking alarm.
(*d*) An inspection of the connectors on the panel. The faulty connector release magnet will be in the operated position

When the connector shaft is released the alarm apparatus returns to normal.

Blocking Alarm on Single Release System. On this system the release of the apparatus is under the control of the calling subscriber. During conversation relay R43 contact 44′ and relay R37 contact 46′ are closed and can only be opened by the release of the connection. Relay R33 contact 46′ is open so long as the called subscriber is speaking.

46. When the called subscriber replaces his receiver relay R33 de-energises, and 46′ contact closes the circuit of the blocking alarm. The 24 volt lamp L46 glows and shows on which connector the connection is being held.

104. Relay R46 is energised and closes the circuit of the blocking signal alarm lamp L104.

105. Relay R46 couples up the circuit of relay R101, thus throwing the fault under the control of the time-lag device, as already described.

If the calling subscriber does not replace his receiver before the time-lag device closes the alarm circuit, relay R103 is energised and brings in the rack lamp, section lamps and alarm buzzer.

The fault is now localised by :—

(*a*) Section lamp.
(*b*) Rack lamp.
(*c*) Lamp associated with the blocking signal alarm.
(*d*) Twenty-four-volt lamp on connector affected.

The attendant restores the connector to normal, thereby freeing the called subscriber's line, and at the same time restoring the alarm circuits to normal, and proceeds to localise the calling line which is causing the trouble.

Group Control Circuit.—A group relay is associated with each panel of connectors to show when they are simultaneously engaged.

106. Relay R107 is normally held short-circuited by the K2 contacts of the connectors in the panel. Immediately the last connector in the panel is brought into use the short-circuit is removed from the relay R107, which is now energised.

108. Relay R107 closes the circuit of the lamp on the traffic observation position.

As soon as the connector becomes free, the K2 contact short-circuits the relay R107 again, and the lamp ceases to glow.

Section 32

FAULT ALARM SIGNALLING CIRCUITS ON THE MOTOR INTERRUPTER RACKS (Fig. 78)

On the interrupter machine racks alarm signals are provided for the following faults :—

(*a*) Main fuse on rack melts.
(*b*) Branch fuse melts.
(*c*) Interrupter spring contact permanently closed.
(*d*) Interrupter spring contact permanently open.

Alarms (*c*) and (*d*) are under the control of the time-lag device.

Rack Main Fuse Melts. 1. When the main fuse melts, the relay R′ is energised, either through the fault or the next circuit brought into use.

2. Relay R′ closes a holding circuit for itself.

3. Relay R′ closes the circuit of the alarm lamp associated with the main fuse, so indicating which particular circuit is affected.

4. Relay R′ closes the circuit of the 5 c.p. rack alarm lamp L4 and the relay R4. The rack lamp L4 indicates which particular rack is affected, circuit 5 glows the section lamp, and circuit 6 causes the alarm buzzer to sound.

When the fuse is replaced relay R′ is short-circuited, releases, and restores the alarm circuits to normal.

Branch Fuse Melts.—These fuses are of the Post Office standard type.

7. When a fuse melts, relay R7 is energised directly from the battery.

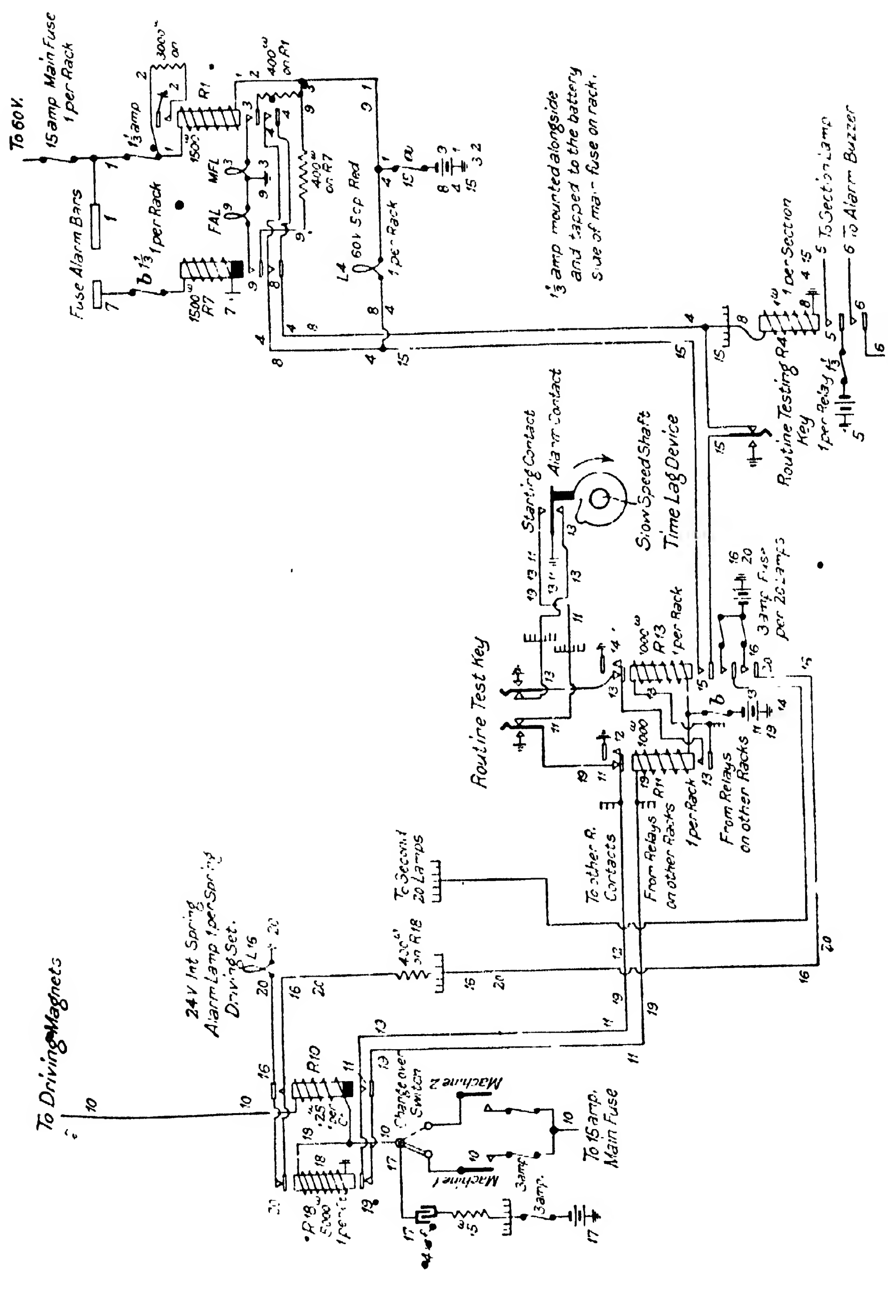


FIG. 78.—MOTOR INTERRUPTER. FAULT ALARM CIRCUIT (SIEMENS).

8. Relay R7 closes the circuit of the rack lamp L4 and energises relay R4. Relay R4 closes circuits 5 and 6, thus glowing the section alarm lamp and sounding the alarm buzzer.

9. Relay R7 closes the circuit of the lamp FAL9 on the rack associated with the branch fuse alarm.

The replacing of the melted fuse restores the alarm circuits to normal.

Interrupter Contact Permanently Closed.—If one of the interrupter springs fails to break contact, the driving magnets which it supplies will be locked in their energised position when taken into use.

10. Relay R10 will then be continuously energised.

11. Relay R10 prepares the circuit of relay R11, which is energised at the beginning of a revolution of the slow speed cam.

12. Relay R11 disconnects itself from the line to the slow speed cam and locks itself.

13. Relay R11 closes and prepares the circuit of relay R13. Relay R11 is now under the control of relay R10 and, should the fault clear itself before the slow speed cam has made one revolution, relay R10 and relay R11 will be released, without the alarm being sounded,

14. If the fault is maintained throughout a revolution of the slow speed cam, relay R13 is energised by the closing of the alarm contact and locks itself.

15. Relay R13 closes the circuit of the rack lamp L4 and relay R4. Relay R4 energising closes the circuit of the section lamp and starts the alarm buzzer

16. Circuit 16 is closed by relay R13 to glow the alarm lamp associated with the faulty springs.

The fault is now localised by :-

(*a*) Section lamp.
(*b*) Rack lamp.
(*c*) Interrupter spring alarm lamp.

When the fault is cleared the alarm apparatus returns to normal.

Two interrupter machines are used, which can be connected alternately to the driving circuit by means of a change-over switch.

17. A spark quench circuit is fitted for each pair of springs.

Relay R10 is energised during the normal operations of the driving magnets, but it is not held long enough for the relay R13 to be brought into circuit over the slow acting cam contact, and consequently the alarm is not given.

Interrupter Contact Permanently Open.—18. As long as the interruptions are taking place regularly, relay R18 remains energised. If a pair of springs fails to make contact, the corresponding relay R18 will be de energised.

19. Relay R18 prepares the circuit of relay R11. If the fault persists long enough, the alarm is given as previously described.

20. Relay R18 closes the circuit of the interrupter spring alarm lamp L16. When the fault is cleared, relay R18 is again energised, and the alarm apparatus is restored to normal.

Section 33

FAULT AND GROUP ALARM SIGNALLING CIRCUITS ON P.B.X. CONNECTORS (Fig. 79)

On the P.B.X. connector racks alarm signals are provided to signal the following faults:—

(*a*) Main fuse on rack melts.
(*b*) Branch fuse melts.
(*c*) Blocking signal alarm for use on single release system.

Alarm (*c*) is under the control of the time-lag device.

A group alarm signal is provided to indicate when all the connectors on one panel are simultaneously engaged.

Main Fuse Melts.

31. When the main fuse melts relay MF′ is energised, either through the fault or by the next circuit brought into use.

32. Holding circuit for relay MF′.

33. Circuit of the alarm lamp MF33 associated with the main fuse, which glows to indicate which particular circuit is affected.

34. Circuit of the 5-c.p. rack alarm lamp and relay DP4. The rack lamp indicates which particular rack is affected, and circuits 35 and 36 close the section lamp and alarm buzzer circuits respectively.

When the fuse is replaced, relay MF′ is again short-circuited, releases and restores the alarm circuits to normal.

Branch Fuse Melts.—These fuses are of the standard Post Office type, as used on manual equipments (Fig. 77).

37. When a fuse melts, relay FA is energised directly, either from battery or from the interrupter.

38. The rack lamp and DP relay energise. Circuit 35 closes to glow the section alarm lamp, and circuit 36 operates the alarm buzzer.

39. Circuit of the lamp FA39 on the rack associated with the branch fuse alarm.

The replacing of the melted fuse restores the alarm circuit to normal.

Blocking Alarm on Single Release System. On this system the release of the apparatus is under the control of the calling subscriber.

40. During conversation, relays R10 and R6 are held energised, and this circuit can only be opened by the release of the connection. Relay R13 contact is open as long as the called subscriber is speaking. When the called subscriber replaces his receiver, relay R13 de-energises and closes the circuit of the blocking alarm circuit.

The 24-volt lamp glows and shows on which connector the connection is being held.

41. Relay BS40 is energised and closes the circuit of the blocking alarm signal lamp.

42. Relay S42 is connected to the starting contact on the slow-speed cam of the time-lag device. At the beginning of a revolution of the cam relay S42 is energised.

43. Relay S42 holding circuit.

44. Circuit of Z44 relay prepared. If the faulty conditions are maintained through one revolution of the slow-speed cam, relay Z44 is energised by the closing of the alarm contact, and locks itself over contact 45.

46. The rack lamp and DP relay circuits are closed. Circuit 5 glows the section lamp, and circuit 6 starts the alarm buzzer.

The fault is now localised by—

(*a*) Section lamp.

(*b*) Rack lamp.

(*c*) Lamp associated with the blocking signal alarm.

(*d*) 24-volt lamp on connector affected.

The attendant restores the connector to normal, thereby freeing the called subscriber's line and at the same time restoring the alarm circuits to normal. He then proceeds to localise the calling line which is causing the trouble.

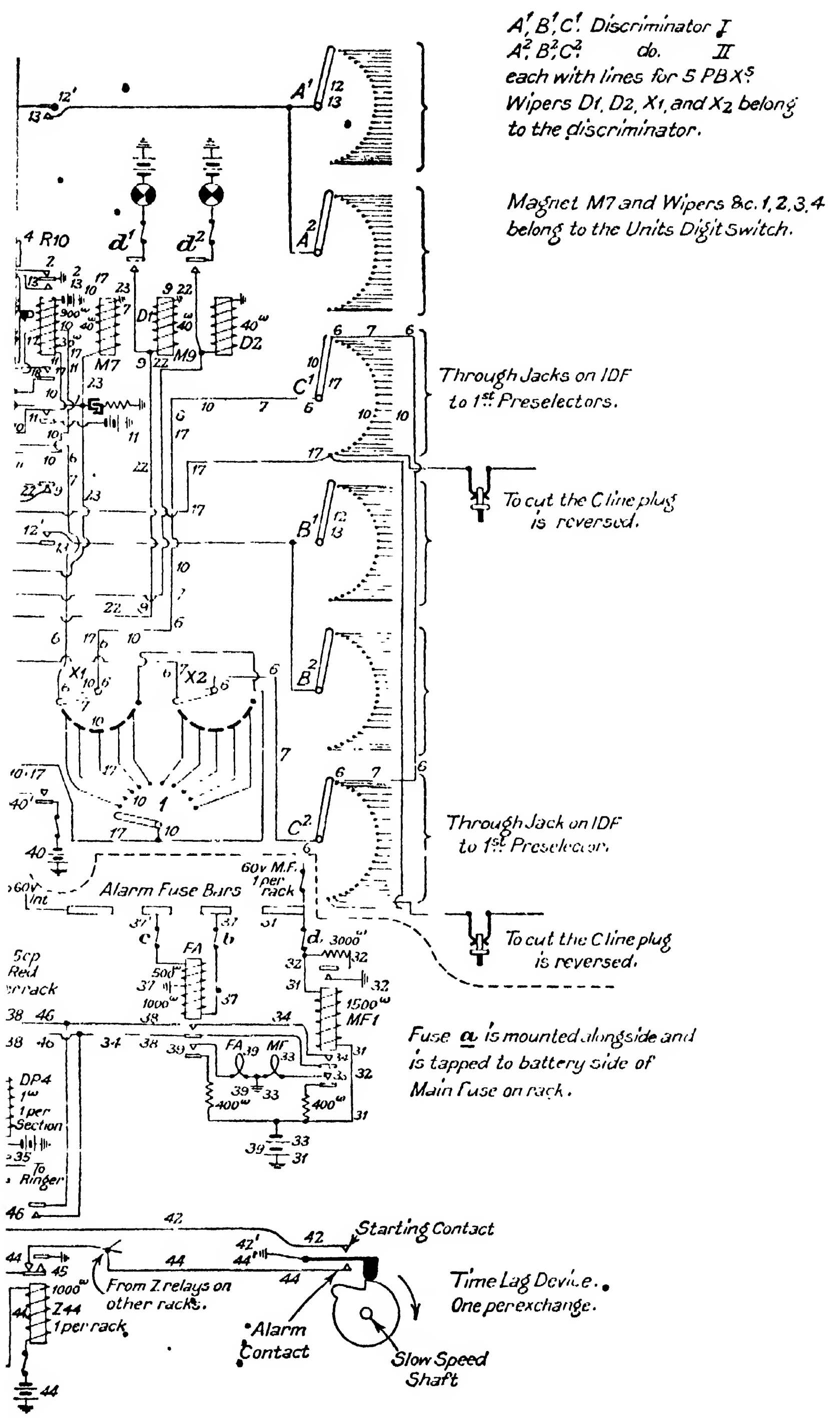
Group Control Circuit.—A group relay is associated with each panel of P.B.X. connectors to show when they are all simultaneously engaged.

47. Relay GX′ is normally held short-circuited by the 47′ contact of relay R4 on the P.B.X. connectors.

48. Immediately the last connector in the panel is brought into use, the short-circuit is removed from relay GX′, which is then energised.

49. Circuit of the lamp on the traffic observation position.

As soon as a connector becomes free the 47′ contact again short-circuits the relay GX′, and the lamp ceases to glow.



…IMINATOR FOR B.P.X. WORKING (SIEMENS).

Section 34

TRUNK-OFFERING APPARATUS AND CIRCUITS (Figs. 80-81)

A special connector for each 100 lines is provided, so that an operator may challenge engaged lines and offer a trunk call to a subscriber.

To allow of the subscriber's full number being dialled, the first two sets of impulses are directed to a special two-digit selector switch (Fig. 80), which connects the trunk offering connector to the particular 100 required.

The two-digit selector is a standard connector mechanism, but the relay set is specially designed to meet particular conditions required. Two two-digit selector switches are

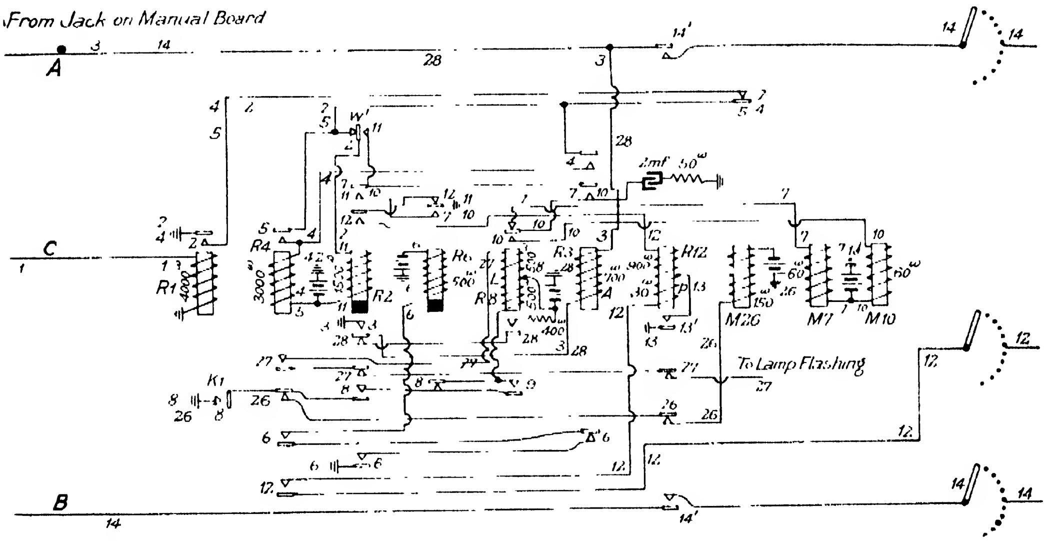


FIG. 80. SIEMENS TRUNK-OFFERING DISTRIBUTOR (TWO-DIGIT SELECTOR) CIRCUITS

provided, and are multipled over the manual board. As there is only one trunk-offering connector per 100 lines, if an operator tries to get through to a trunk-offering connector already in use, a lamp-flashing signal must be given back from the two digit selector.

The trunk-offering connector is also a standard connector mechanism, but circuit arrangements allow of engaged lines being entered without in any way interfering with the connection.

The circuits are numbered in the order of operation, and are as follows :—

The operator inserts a plug into a line jack of a two-digit selector and moves the dialling key.

1. Relay R′ is energised over the third conductor circuit.
2. Relay R2 energises.
3. Relay R3 is energised by battery from the dialling circuit over the A wire.
4. Relay R4 is energised in parallel with relay R2.

5. Holding circuit of relay R4, which is now independent of relay R3.

The circuit is now ready to receive impulses.

The operator now dials the first digit of the required number, and the line is interrupted a number of times, corresponding to the value of the number called.

6. At the first interruption relay R3 is de-energised. Relay R6 is energised. R6 is slow to release, and remains energised during each train of impulses.

7. On the completion of the first impulse, relay R3 is again energised, and the lifting magnet M7 receives an impulse. The shaft is raised one step and contact K′ closes.

The remainder of the first set of impulses are now directed to the lifting magnet by circuit 7, and the wipers are stepped up to the required level.

As soon as the impulses are finished, relay R3 is held energised by battery from the dialling circuit. Circuit 6 is held open, and relay R6 releases.

8. Relay R8 is now energised.

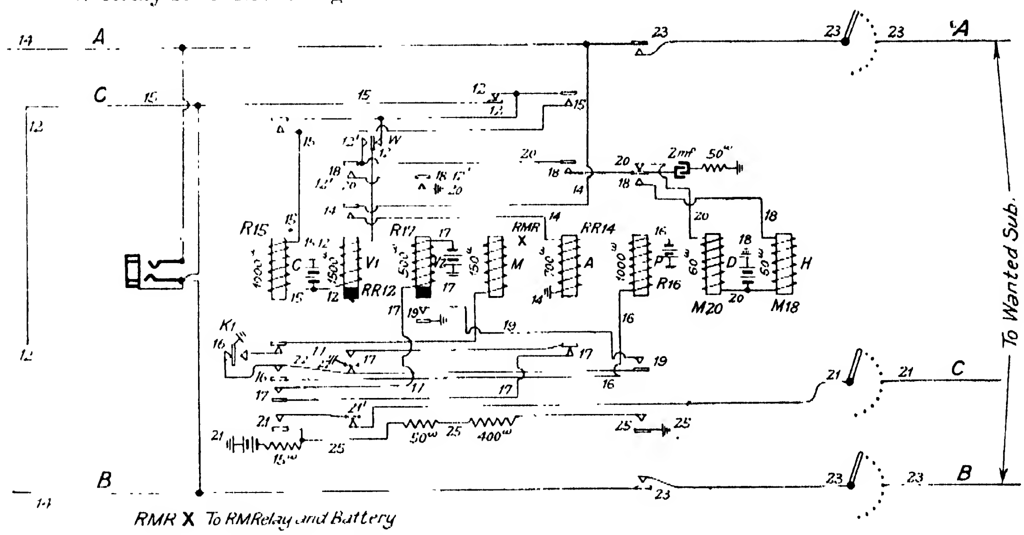


Fig. 81.—Siemens Trunk-offering Connector Circuit.

9. Contact 9 closes a holding circuit for relay R8, which is now independent of relay R6. Relay R8 disconnects the lifting magnet M7, and couples up the rotary magnet M10. The operator now dials the hundreds digit, and, as before, relay R6 is energised.

10. The impulses are directed to the driving magnet M10.

11. At the first rotary step the contact W′ disconnects relay R2 from the C wire and throws it under the control of relay R6.

The wipers are now stepped round to the required contact.

Relay R3 is held energised, circuit 6 is open and relay R6 de-energises.

12. Relay R6 opens circuit 10 of relay R2, which is, however, slow to release, and before it can release, if the required trunk-offering connector is free, relay R12 is energised from battery at the trunk connector.

13. Holding circuit of relay R12. The called circuit is engaged through the 30-ohm winding.

14. Relay R12 contacts 14′ join through the A and B wires to the offering connector.

Relay R2 now de-energises.

Relay R6, by opening circuit 3, disconnects the relay R3 from earth.

Circuit 8 is opened and releases relay R8.

The operator is now connected through to the trunk-offering connector, and the A and B wires are quite free of bridges and apparatus. Relays R4 and R12 are held energised.

When the trunk-offering connector is taken into use, relay RR12 (Fig. 81) is energised and connects the relay RR14 to the A wire.

15. Relay RR14 is energised and connects relay R15 in parallel with relay RR12.

16. Relay R16 is energised.

17. Relay R17 is energised, and the connector shaft is lifted the required number of steps over circuit 18 (as previously explained).

After the impulses, circuit 17 is held open and relay R17 releases.

19. Circuit 19, over which relay R16 was held after K′ contact operated, now opens, and relay R16 is released.

20. Relay R16 de-energising, opens circuit 18, disconnects magnet M18, and connects up M20 in readiness for the last series of impulses.

The connector wipers are then stepped round to the required contact, and relay R17 is released as previously described.

Relay R17 opens circuit 12′, and relay RR12 is released.

Circuit 14 is opened to disconnect relay RR14 from the A wire.

21. Testing circuit over the C wire to the cut-off relay on the wanted subscriber's preselector.

22. Relay R16 is energised over circuits 16 and 22.

23. Relay R16 contacts close, connecting the A and B wires 14 through to the line called.

25. A local circuit. The arrangement of resistances in this circuit is such that the point to which the C wiper is connected is approximately at the same potential as that already existing on the lead of an engaged connection. Consequently the latter is not in any way disturbed when a trunk-offering connector is set on the line.

Should the wanted subscriber have released his connection whilst the connector is being set, the cut-off relay of his preselector is energised over circuit 21.

The line is engaged to other connectors by the low resistance (15 ohms), which takes the place of the 30-ohm coil of relay R16, used in an ordinary connection.

The operator informs the wanted subscriber that he is required for a trunk call, and asks him to release his connection. She then releases the two digit selector and the trunk-offering connector, and sets up the trunk call in the ordinary way.

Release.—When the operator withdraws the plug from the jack, relay R′ (Fig. 80) is de-energised. Circuit 4 opens and releases relay R4.

Circuit 12 opens and releases relay R12.

26. Circuit of the release magnet M26.

Contact 14′ opens to prevent interference with engaged lines, whilst the connector is being restored to normal.

The connector shaft rotates and falls, and the K and W contacts are returned to their normal positions, the circuit of the release magnet being finally opened at K′.

When circuit 12 was opened the circuit of relay RR12, at the trunk-offering connector, was interrupted. This connector now releases in a manner similar to that just described.

When a Trunk-offering Connector is engaged. The connector is set on the contacts of the wanted line as already described.

When relay R17 closes circuit 16–19, relay R16 cannot be energised because it is shunted by the 30-ohm coil of the relay R16 of the connector already engaging the line.

27. When relay R2 is released a little later, relay R8 is intermittently energised through the lamp-flashing contact.

28. Lamp-flashing signals are transmitted to the operator, over the A wire, to the supervisory relay and earth. The operator is thus informed that the trunk-offering connector, in the required hundreds group is already engaged.

Section 35

PRIVATE BRANCH EXCHANGE TRUNK-OFFERING CONNECTOR (Fig. 82)

A special P.B.X. connector is provided on each group of 10 P.B.X.'s, so that an operator may challenge an engaged line, and offer a trunk call to the subscriber.

To allow of the subscriber's full number being dialled, the first two sets of impulses are directed to a two-digit selector, which selects the P.B.X. trunk-offering connector in the particular group, as already described (Fig. 80).

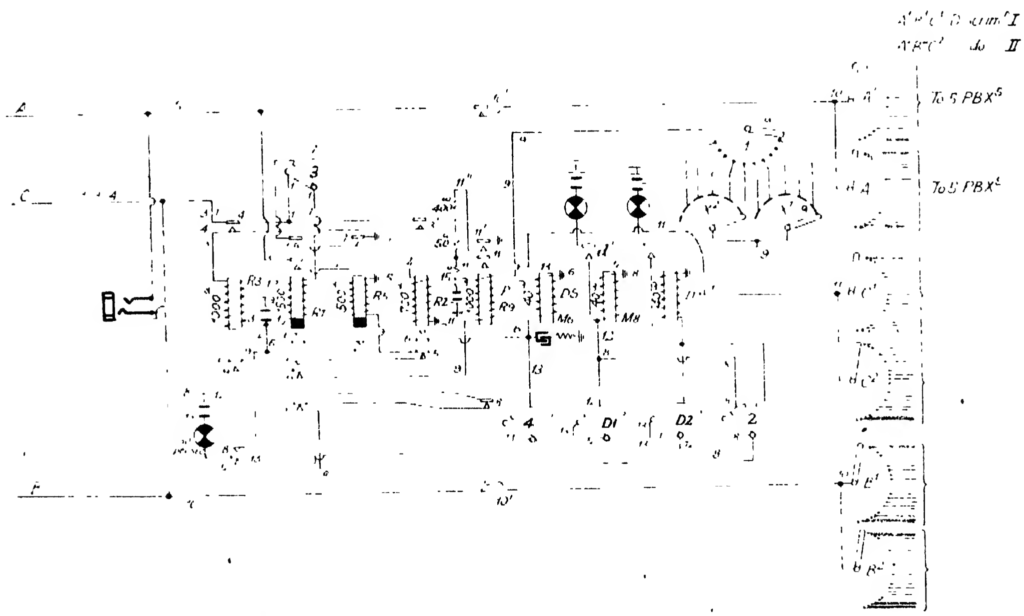


Fig. 82.—Siemens P.B.X. Trunk-offering Connector Circuit.

When a trunk call comes through for a P.B.X. subscriber, the operator sets up the call in the usual way. If all the lines on the P.B.X. are engaged, she releases the connection, and brings the trunk-offering apparatus into operation. The trunk-offering connector enters the first line in the particular P.B.X. group required, and the operator proceeds to offer the call. If the subscriber agrees to take it he is requested to hang up his receiver. The operator then releases the trunk offering apparatus, and sets up the call in the ordinary way.

The circuits are numbered in the order of operation, and are as follows:

1. When the P.B.X. trunk-offering connector is taken into use relay R′ energises, over the C wire, to earth at the two-digit selector.

2. The relay R2 is energised over the A wire to battery at the trunk operator's position.

3. Relay R3 is energised.

4. Holding circuit for relay R3, which is now independent of contact 3′.

The circuit is now ready to receive impulses. The operator dials the units digit of the wanted subscriber's number, and at the first interruption relay R2 is released.

5. Relay R5 is energised.

6. At the end of the first interruption relay R2 is again energised, and the digit switch driving magnet M6 receives an impulse.

Relay R5 is slow to release, and holds its armature during the series of impulses. The remainder of the impulses are directed to the driving magnet M6 over circuit 6.

Wipers 1, 2, 3, and 4 of the digit switch are rotated a number of steps, corresponding to the number dialled.

7. Relay R′ is now held over wiper 3 in its off-normal position, and is under the control of relay R5.

At the conclusion of the first series of impulses, relay R2 is held energised, and, since circuit 5 is open, relay R5 is released.

Circuit 6 is open and disconnects the driving magnet circuit of the digit switch.

Circuit 7 opens the holding circuit of relay R′, which is now released.

Circuit 2 is open, and disconnects the relay R2 from the A wire.

8. The driving magnet of the discriminator is joined up.

9. The discriminator wipers commence to rotate, and, as soon as a wiper X comes into contact with the first line of the group, on which the wiper 1 of the digit switch is resting, relay R9 is operated.

Circuit 8 is opened and disconnects the driving magnet of the discriminator, and the wipers come to rest.

10. The contacts 10′ connect the A and B wires to the wanted line.

11. If the line should be freed whilst the connection is being set up, the cut off relay on the preselector will be energised over the C wiper of the discriminator.

11′. A local circuit, through resistances 15, 50 and 400 ohms, to earth. The arrangement of resistances in this circuit is such that the point to which the C wiper is connected is approximately at the same potential as that already existing on the lead of an engaged connection. Consequently, the latter is not in any way disturbed when a P.B.X. trunk offering connector is set on the line.

The line is engaged to other connectors by the low resistance 15 ohms, which takes the place of the 30 ohm coil of the relay R9 used in an ordinary connection.

The operator informs the wanted subscriber that he is required on a trunk call, and asks him to release his connection. She then releases the two-digit selector and the trunk-

offering connector, and sets up the trunk call over the ordinary selectors and the P.B.X. connector.

Release of the Connection.—When the operator withdraws the plug, the two-digit selector is released, and the relay R3 circuit is broken.

Circuit 3 –4 is opened and disconnects relay R3 from the C wire.

Circuit 9 is opened and disconnects relay R9.

Contacts 10′ open and prevent interference on engaged lines during the return of the switches to normal.

Circuit 11 is opened and opens the equipotential circuit and disconnects battery from the C wire.

12. The circuit of the driving magnet M8 of the discriminator is completed. The discriminator wipers are moved round and brought to rest on the normal contact, because the driving magnet circuit is cut by a wiper D.

13. The driving magnet M6 of the digit switch is now brought into circuit, and receives impulses. The digit switch wipers return to normal, and the driving magnet circuit is cut at wiper 4.

All the relay contacts and switch wipers are now in their normal or resting position.

Section 36

SIEMENS TESTING CONNECTOR (Fig. 83)

One testing connector is fitted for each group of 100 subscribers' lines in the exchange. These connectors are wired to testing jacks fitted on the test clerk's desk.

Associated with each testing jack is a dialling jack, on which lines from the impulse

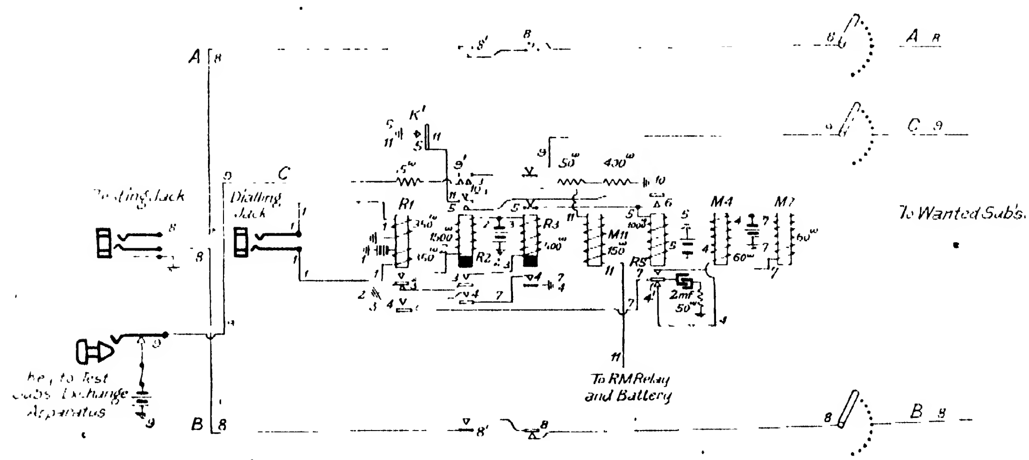


FIG. 83.—SIEMENS TESTING CONNECTOR CIRCUIT.

relay of the testing connector terminate. The setting up of the connector is thus quite independent of the testing leads.

By this arrangement the test clerk can, after setting the connector on a particular line, cause it to move on to another line on the same level without having to release the connection. This is particularly useful for making routine tests of consecutive lines.

The testing connector is a standard connector mechanism, but the circuits are so arranged as to give a straight metallic circuit over the A and B wires for testing purposes.

The circuit arrangements are such that the connector can be set on an engaged subscriber's line without interfering with the existing connection.

By pressing a key, which is associated with each testing jack, the testing officer can release the cut-off relay on a subscriber's preselector, and can then energise the subscriber's line relay in order to test the apparatus for making an outward call.

The circuits are numbered in the order of operation, and are as follows :—

All the relay contacts and the switch arms are shown in their normal or resting position.

1. When the test clerk inserts a plug in the dialling jack the relay R′ is energised over the loop.

2. Relay R2, slow to de-energise, is energised, and connects up the A and B wires to the wipers, and also prepares the testing circuit over the C wiper of the connector.

The circuit is now ready to receive impulses.

The test clerk dials the tens digit of the required number, and as the dial returns to normal the circuit of the relay R′ is interrupted a number of times corresponding to the number dialled.

3. At the first interruption relay R′ de-energises, and relay R3 is energised. Relay R2 being slow-acting is not released.

At the end of the first impulse the relay R′ is again energised, and relay R3, being also slow-acting, holds its armature during the series of impulses.

4. The lifting magnet M4 receives an impulse, and the shaft is lifted one step, and contact K′ closes. At the conclusion of the series the relay R′ remains energised, and, since circuit 3 is open, the relay R3 is released.

5. Relay R5 is energised.

6. Contact 6 closes a holding circuit for relay R5, which is now independent of relay R3.

7. Circuit 4 is open at 4′, magnet M4 is disconnected, and magnet M7 joined up in its place.

The test clerk now dials the units digit of the wanted number.

At the first interruption relay R3 is again energised over circuit 3. Contacts in the A and B wires are opened to guard against interference on engaged lines whilst the wipers are being rotated. A contact on the C wire is also opened, to guard against interference on the C lead.

The impulses are directed to the rotary magnet by the opening and closing of circuit 7.

At the end of the series of impulses circuit 3 is open, relay R3 de-energises, and opens the circuits 4 and 7 of the motor magnets.

8. The A and B wires are now joined through to the wanted subscriber.

9. If the wanted line is free, a circuit is completed through the cut off relay of the preselector to earth.

The line can now be tested over the A and B wires, which form a clean metallic circuit, from the testing jack to the subscriber's instrument.

10. The subscriber's cut-off relay R3, Fig. 72, is shunted by 450 ohms resistance, but is not thereby prevented from being operated.

The arrangement of resistances, 15, 50 and 400 ohms, is so chosen that the point to which the C wiper is connected is approximately at the same potential as the C wire in an engaged connection. The latter is, therefore, not interfered with if the testing connector is set on a busy line.

If the test clerk wishes to test a subscriber's exchange apparatus, he sets the connector on the subscriber's line and presses the key associated with the jack of the test connector in use. The relay R3 on the subscriber's preselector is thereby released. The test clerk can now, by bridging the A and B wires, cause the subscriber's line relay to operate. Connection is thus set up over a first and second preselector, with a free first selector, and the test clerk can, by sending impulses over the A and B wires, cause a connection to be set up with any line in the exchange.

Release of the Testing Connector. When the plug is withdrawn, the relay R′ is released.

Circuit 3 is completed and relay R3 momentarily energised.

Circuit 9 over the C lead is opened, and the relay R3 on the first preselector is de-energised.

Circuit 2 being open relay R2 de-energises, opens circuit 3, and relay R3 then de-energises.

The A and B wire contacts 8′ are open to prevent interference with engaged lines, whilst the connector is returning to normal.

Contacts 9′ and 10′ are open to cut off the resistances forming the equipotential circuit. They also disconnect the C wiper from battery.

Circuit of the release magnet M11.

Circuit 5 is opened, and relay R5 de-energises.

The connector returns to its normal position, in which the circuit of the release magnet is open at K′ contact.

All the relay contacts are now in their normal or resting position.

Section 37

PRIVATE BRANCH EXCHANGE TESTING CONNECTOR (Fig. 84)

One P.B.X. testing connector is fitted for each group of 10 P.B.X. lines in the exchange. These connectors are wired to testing jacks fitted on the test clerk's desk.

Associated with each testing jack is a dialling jack, on which the lines from the impulse relay of the testing connector terminate. The setting up of the connector is thus quite independent of the testing leads

The P.B.X. testing connector is a standard P.B.X. connector mechanism, but the circuits are arranged to give a clean metallic circuit over the A and B wires for testing purposes.

The stepping round of the discriminator wipers is entirely under the control of the test clerk's dial. The discriminator has 25 contacts, and the line desired may be beyond the range of one set of impulses. The test clerk is, however, able to supplement the series until the wipers have been stepped round to the required contact.

A record of the order in which the various lines of any P.B.X. are arranged on the discriminators will be kept by the test clerk, who is thus able to test any particular line, or to make consecutive tests, without releasing the connection of all the lines on any discriminator. The circuit arrangements are such that the P.B.X. connector can be set on an engaged subscriber's line without interfering with the existing connection.

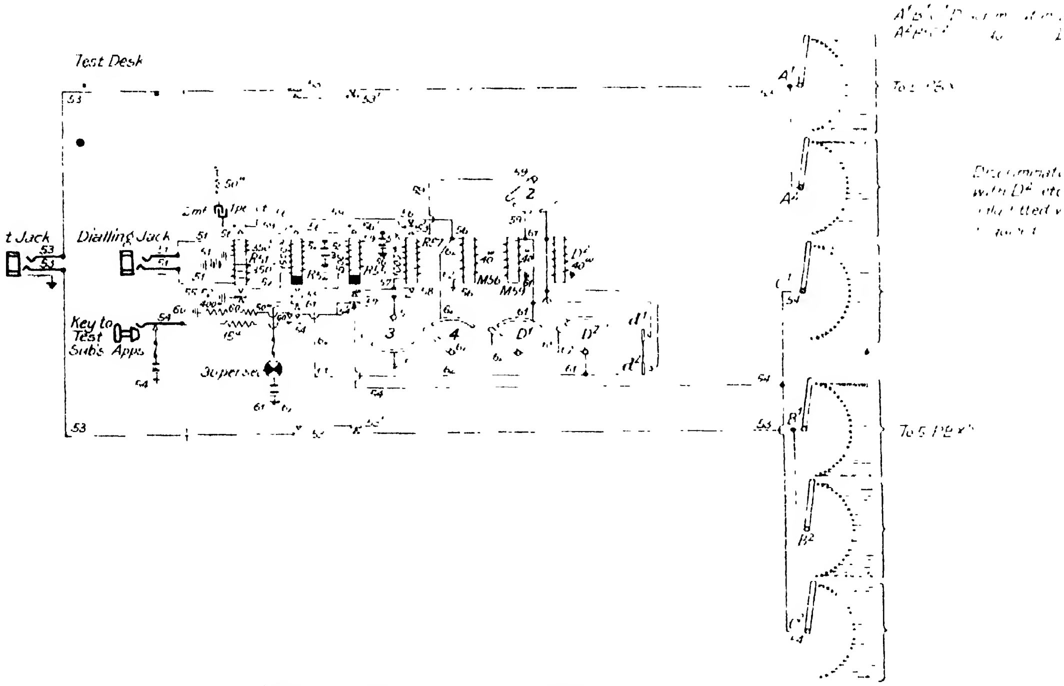


FIG. 81. SIEMENS P.B.X. TESTING CONNECTOR CIRCUIT.

Associated with each testing jack is a key, by depressing which the test clerk can test the operation of a subscriber's calling apparatus.

The circuits are numbered in the order of operation and are as follows:—

51. When the test clerk inserts the plug into a dialling jack, the relay R51 is energised over the loop.

52. Relay R52 is energised.

53. A and B wires through to wipers.

54. Test circuit over the C wiper of the discriminator prepared. The circuit is now ready to receive impulses.

The test clerk dials the units digit of the required number, and, as the dial returns to normal, the circuit is interrupted a number of times corresponding to the number dialled.

55. At the first interruption, relay R51 de-energises, and relay R55 is energised. Relay R55 is slow to release, and remains energised during the impulses. At the end of the first interruption the relay R51 is again energised.

56. Circuit of the digit switch driving magnet M56. The wipers 2, 3 and 4 of the digit switch move from their normal to their off-normal positions.

The remainder of the impulses in the series are directed to the driving magnet M56 of the digit switch by circuit 56.

At the conclusion of the first set of impulses relay R51 is held energised, and, since circuit 55 is open, relay R55 de-energises.

Contact 56′ opens the circuit 56 of the digit switch driving magnet M56.

57. Relay R57 is energised, through wiper 3 of the digit switch, off-normal contact and earth.

58. Holding circuit for relay R57, which is now independent of contact 57′.

The test clerk now dials the impulses for setting the discriminator on the contacts of the wanted line.

59. The discriminator driving-magnet circuit is completed through wiper 2 of the digit switch, off-normal contact, and driving magnet of discriminator I. or II. Relay R55 is held energised.

Contacts 53′ are open and present interference on engaged lines during the rotation of the discriminator wipers.

Contact 54′ opens and cuts battery off the C wiper of the discriminator, to prevent interference with the test leads of engaged lines.

If necessary, further impulses may be sent in order to set the discriminator on the wanted line.

At the conclusion of each set of impulses, relay R55 is released.

Contact 59′ opens the circuit of the discriminator driving magnet.

Contacts 53′ close and connect the A and B wires from the testing jack to the wanted line.

Circuit 54 is completed, and, if the wanted line is idle, a circuit is closed through the C wire to the cut-off relay of the subscriber's preselector and earth, operating the cut-off relay as in an ordinary call.

The subscriber's cut-off relay is shunted by 450 ohms resistance, but is not thereby prevented from being operated.

60. The arrangement of resistances, 15, 50 and 400 ohms, is such that the point to which the C wiper is connected is approximately at the same potential as the C wire in an engaged connection. The latter is, therefore, not interfered with if the P.B.X. testing connector is set on a busy line.

The line can now be tested over the A and B wires, which form a clean metallic circuit from the testing jack to the subscriber's instrument.

If the test clerk wishes to test a subscriber's exchange apparatus, he sets the connector on the subscriber's line and presses the key associated with the jack of the P.B.X. testing connector in use.

The cut-off relay on the subscriber's preselector is thereby released. The test clerk can now, by bridging the A and B wires, cause the subscriber's line relay to operate. Connection is thus set up over a first and second preselector with an idle first selector, and the tester can, by sending impulses over the A and B wires, cause a connection to be set up with any line in the exchange.

By sending a further series of impulses the test clerk can again operate the discriminator driving magnet and cause the P.B.X. testing connector to be set up on another line.

Release of the P.B.X. Testing Connector.—When the plug is withdrawn, relay R51 is released. After a short interval, relay R52 is also released as circuit 52 is open.

When relay R51 de-energised relay R55 was momentarily energised. Circuit 54 over the C wire is opened, and the cut-off relay on the subscriber's preselector is released.

Circuit 55 is open, and relay R55 de-energises.

Relay R52 opens the A and B wires to prevent interference on engaged lines while the discriminator is returning to normal.

Contact 54′ opens the circuit of the resistances forming the equipotential circuit, and at the same time disconnects the C wiper from the battery.

61. Circuit of the discriminator driving magnet M59.

62. When the discriminator has returned to its normal position, the driving magnet is disconnected, and the digit switch driving magnet M56 is joined up.

The digit switch returns to its normal position, in which the circuit through the driving magnet is broken.

The circuit of relay R57 is opened at wiper 3 of the digit switch.

All the relay contacts and switch wipers are now in their normal or resting position.

DIRECTOR OF INDUSTRIES LIBRARY BENGAL

DIRECTOR OF INDUSTRIES. LIBRARY 13-JUL 1925 BENGAL.

MACHINE SWITCHING SYSTEMS WITH CONTINUOUS DRIVE

THE LORIMER, A CANADIAN SYSTEM

was the first of this type. It is better known in connection with the

WESTERN ELECTRIC COMPANY'S ROTARY SWITCH SYSTEM

which uses a 200-line switch with 10 levels of 20 sets of line terminals and 10 sets of wipers or brushes, one set being tripped into engagement when a line is called; and

WESTERN ELECTRIC COMPANY'S PANEL SYSTEM

with 500-line switches, in which each bank has 100 sets of line terminals in the height and 30 sets in the width, so that 30 switches on each face can make connection. There is a set of wipers per switch per bank carried on a vertical shaft, and a set of wipers or brushes is tripped into engagement when a line is called.

The W. E. Co.'s systems may be either decimal or non-decimal.

Section 38

THE WESTERN ELECTRIC CO.'S SYSTEMS

There are two systems—the *Rotary* and the *Panel*.

The Rotary machine switching system is well known, and the Post Office have introduced it into several exchanges in this country. The *Panel* system has been fitted in a few exchanges in the United States, but is practically unknown outside these, but is now proposed for London. It is likely, however, to be more widely known soon, as it is advocated as being the most suitable system for very large areas.

The *Rotary* system is so named because the switches have rotary motion only. The switches have a capacity for 200 lines.

The *Panel* system has vertical motion only, and the switches have a capacity for 500 lines.

The Rotary System. This system differs very considerably from the Strowger systems previously considered.

It has switches with double the capacity, viz., 200 lines. These have rotary motion only, a set of brushes being provided for each level. The brushes are normally out of engagement with the terminals. On the final switch the tens digit trips a particular set of brushes into engagement with the terminals.

The impulses sent out from the subscribers' dials are received by registers, and are then forwarded to the respective switches at exactly the correct speed. This is controlled by the distant switch, which sends back to the register an impulse for each step it takes to cause the register to give up its impulses one by one until zero is reached. This is known as *revertive impulse control*.

Translation is required to allow the decimal system of impulsing to cause a set of brushes to connect in either the first or second hundreds group of the 200-line switch.

The switches are mechanically driven by light shafting which is continuously rotating, a disc on the shafting being brought into engagement with a disc on the switching electromagnetic means, so as to rotate the switch brush-carriage, and the like.

Other differences will be noted in describing the system in detail, but sufficient has been disclosed to indicate that the system has many interesting and novel features.

The Power Drive is the characteristic mechanical feature of this system.

The Electro-mechanism. A small motor drives the shafting, so that it is rotated continuously. The latter may consist of a main horizontal shaft run near the floor level, from which runs a vertical shaft for each vertical row of switches (Fig. 85). The electromagnetic clutch is a very simple but very effective device.

Power thus taken from continuously running shafting allows of heavier and mechanically stronger switches being used. There can be greater pressure between the brushes and the contacts than on other systems. The switches can be moved at the most efficient speed. The comparatively heavy brush carriages are set readily in motion, when they are driven with a smooth continuous motion, which eliminates all vibration and jarring. High speed may be given to all moving parts, this being limited only by the accuracy in stopping the brushes.

Reserve motors are provided which can be readily switched in when required. These

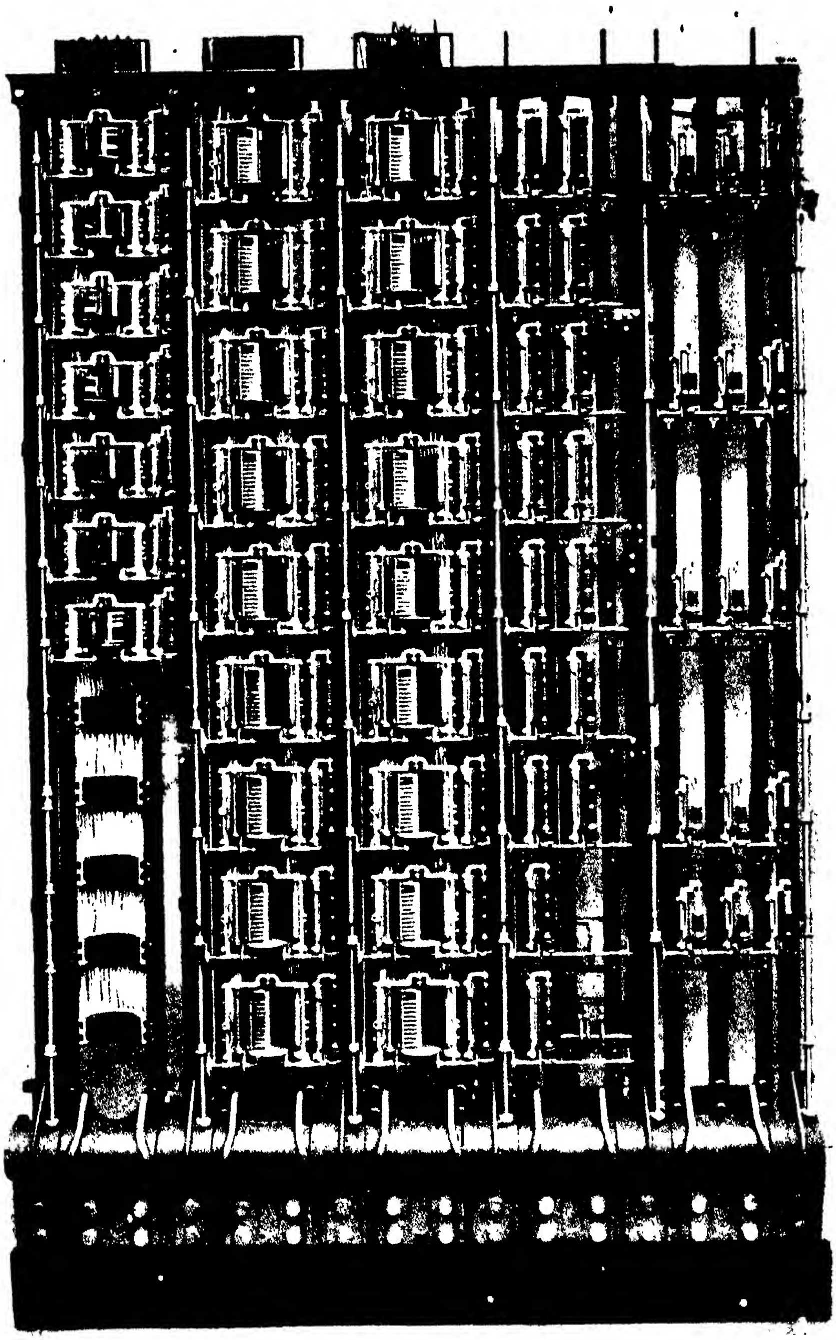


FIG. 85.—A WESTERN ELECTRIC CO. ROTARY SYSTEM EXCHANGE.

can be operated from the battery, so that the exchange is independent of external power, during a breakdown. Portions of the shafting may be stopped during periods of light traffic, and at night all shafting may be stopped. An automatic device starts up the shafting when a call is made. The power required for the shafting is very small, a 2-H.P. motor being sufficient for a 10,000 line exchange.

A general view of a small installation is shown in Fig. 85.

Magnetic Clutch.—An iron disc is fitted on the rotating shaft, and an iron ring, mounted on a flexible diaphragm, is associated with the switch moving part so arranged that, when current is passed through the power magnet associated with the switch, the latter ring or disc is deflected until it meets the rotating disc near the edge, when the deflected disc is caused to rotate at the same speed as the shaft.

In Fig. 86, D1 is a short shaft for a switch, held in bearings D2, and coupled to the rotating vertical shaft by the bevel gear D3. The latter shaft rotates at a speed of 31 revolutions per minute.

The disc D4 is fixed on the revolving shaft D1, and the second disc B5, placed at right angles, is fastened by a diaphragm to the shaft B. To rotate the carriage the fixed electro-magnet PG is energised, when the edge of B5 is pulled into contact with D4 so that they rotate together, and the brush carriage is carried round. To stop the brush carriage the circuit of magnet PG is opened. To prevent the inertia of the carriage carrying the brush beyond the terminals, the magnet HG is energised immediately the power circuit is opened.

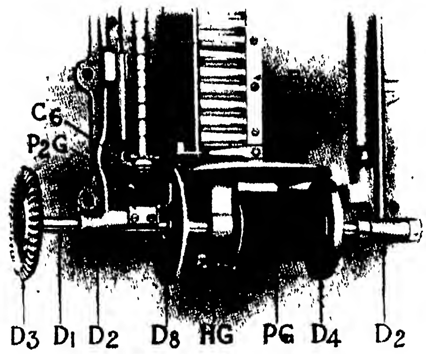


FIG. 86. ROTARY SYSTEM POWER DRIVE.

To the left of the brushes is shown the trip spindle, whose use will be explained later. This is rotated and stopped in a manner somewhat similar to the brush carriage. The disc, with diaphragm D8, is attached to the rotating shaft D1, and a second disc C6 is attached to the vertical spindle. When the magnet P2G is energised, D8 is attracted, and the spindle is rotated. No holding magnet is necessary to stop the shaft instantly.

This form of drive is very simple, the parts are subject to little wear, and that is self-adjusted. The clutch and release are almost instantaneous, and thus suitable for fast selective operations. The power needed for closing firm contacts is readily transmitted without slipping.

DIRECTOR OF INDUSTRIES LIBRARY -4 JUL 1925 BENGAL

Section 39

THE APPARATUS

The Line Switch (Fig. 87).—A plurality of these, sufficient to meet the traffic requirements, have the corresponding bank terminals multipled together. Each has terminals for 60 subscribers' lines in rows of 20, there being four rows of terminals for each level of 20 lines. The terminal arc subtends an angle of 120 degrees. The rotatable shaft carries three sets of four brushes spaced at 120 degrees round the shaft, and are so spaced on the vertical shaft

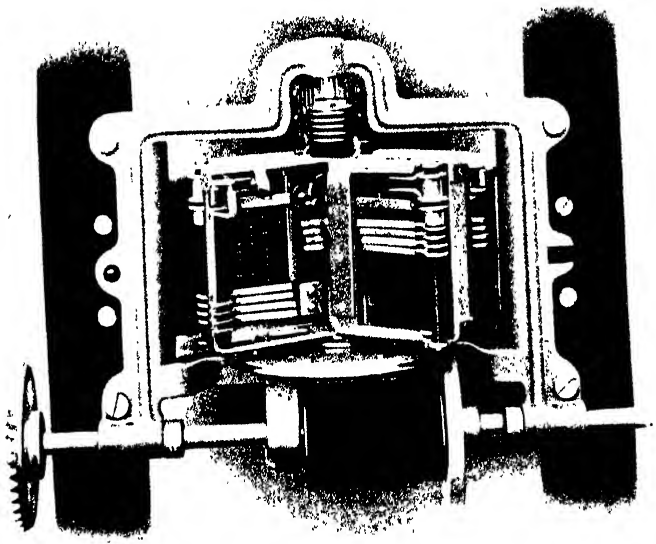


Fig. 87. Rotary System Line-finder Switch.

that each set engages with a different level of terminals. The brushes are associated with the trunks, and the switch is therefore a backward hunter, *i.e.*, when a subscriber calls the trunk hunts to find the calling line. When a call is made, all the switches associated with that group of subscribers start to hunt, and the one that first touches the calling line stops and makes that line test busy to all the others.

It will be seen that the magnetic clutch is arranged as described for Fig. 86, so that when the magnet is energised, the brushes rotate. There is no latching device, and therefore no brush chooser. There is no normal or home position, the brushes remaining in the position in which they were last engaged, until another call is received. When the brushes start to hunt, the brushes of the plurality are thus in different positions in the arc so that a very small amount of travel may be necessary to find the line. There is a toothed rack and a brush or spring carried by the shaft, which makes contact with a tooth between the line of the terminals, to ensure that the brushes are properly centred on the terminals. The trunks

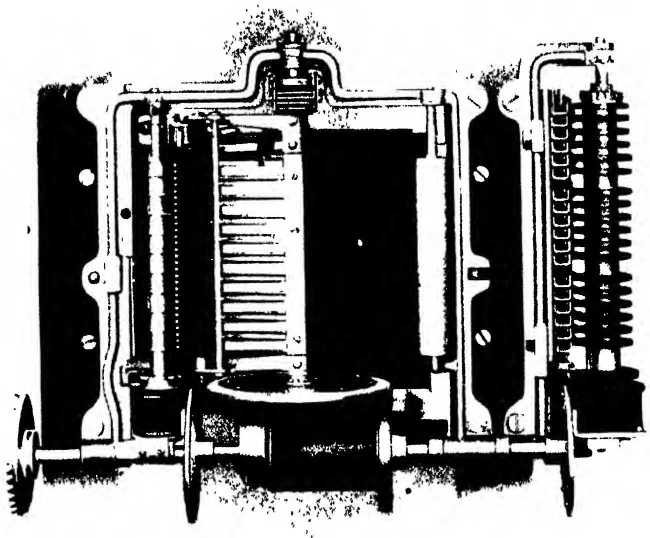


FIG. 88. W. E. Co.'s Rotary System Selector with Sequence Switch.

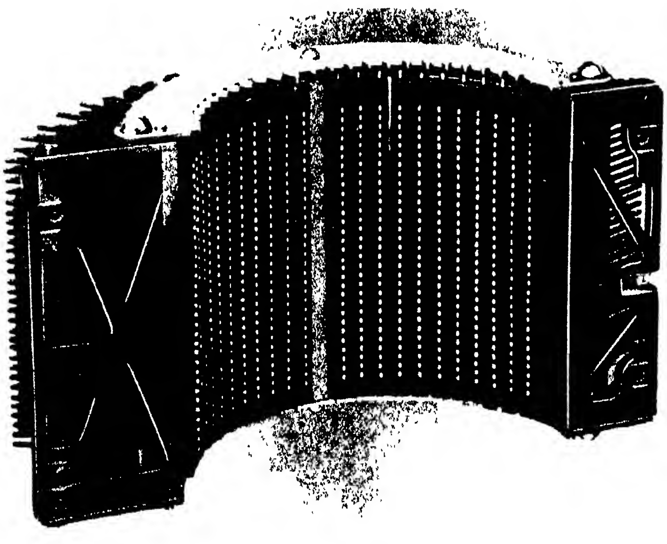


FIG. 89.—Rotary System Terminal Bank of a Selector.

on the brushes may connect with a register, or may connect with a second similar switch which connects with a register.

The Selector (Fig. 88).—This figure shows a brush chooser on the left, a bank of contacts with 10 sets of brushes on a shaft centrally, and a sequence switch on the right. The brush carriage is shown in its normal position.

Fig. 90. Vertical Strips of Terminals with Ribbon Cable (W. E. Co.'s Rotary System).

The switch consists of two main parts, the terminal arc or bank of contact terminals, and the frame carrying the operating parts.

The Banks (Fig. 89).—From the illustration it will be seen that there are 22 vertical strips or plates of terminals (a side view of a strip is shown in Fig. 90). There are 30 terminals on each strip, moulded in a block of electrose. These strips are fixed top and bottom into plates so that they are placed like a number of books in a shelf. The final switch has only 20 strips. Three terminals in the height of a strip are used in connection with each line. The vertical strip therefore carries terminals for 10 lines, and the brushes sweep over 22 or 20 lines respectively.

The frame to which the banks are rigidly attached carries in its centre the brush carriage, pivoted top and bottom. To the left is pivoted the spindle of the brush chooser. To the right is a roller which resets the brushes as they pass on their way in completing a rotation to normal. Further to the right in a separate frame is a sequence switch which will be dealt with later.

The Brush Carriage and Brushes (Fig. 91).—There are 30 brushes on a carriage, arranged in 10 sets of three. A single brush is shown at the bottom right hand side of the picture, and relatively in the position it occupies in the main picture. The 30 comb-springs, shown to the left of the brushes, are separately insulated from, but secured to the rotating spindle. They are arranged in sets of three, each set being associated with the two line wires and the test wire. The corresponding springs of the sets are multipled together, and connected to the commutator rings shown at the top of the shaft. Each comb spring engaged with the left projection on a brush. The brushes are threaded on a spindle, as shown at the near angle of the picture. The comb spring tends to force the upper and right end of the brush outwards, as shown in the projection of the fourth set of brushes from the top. They are, however, normally kept retracted by latch or trigger devices, one of which is shown above the single brush. These also are threaded on a

spindle fitted behind the picture, and on the extreme right, and are pressed against the ends of the brushes by other comb springs. When the carriage starts to rotate the line of brushes passes the brush chooser, which has had one particular tooth set in position. It now engages with the trigger, controlling one set of brushes so that they are unlatched, and then forced forward to make contact with the terminals as the carriage moves.

The shaft also carries at the top a roller, mounted on a lever arm (shown at extreme top and right), which engages the teeth on the toothed rack, shown forming the top of the bank, Fig. 89, for mechanical centring. A second lever arm (to the left of the other) makes contact with the teeth of the toothed rack to send back impulses, as will be described later. The latter does not touch the rack when standing between two teeth.

The disc shown at the bottom of the shaft is part of the magnetic clutch. The part nearer the centre is the diaphragm, with an outer ring of iron to engage with the disc on the shafting.

The Brush Chooser (Fig. 92, see also Fig. 88).—The spindle has 10 projections, or teeth arranged spirally round it. By different amounts of rotation a different projection will lie in the path of the brushes, to pull a latch away from the brush ends, to allow a set to move forward. A power cam, shown above the magnetisable disc, has 11 notches, one for each projection and one for normal. A roller contact spring engages with it and is shown between the cam and the frame.

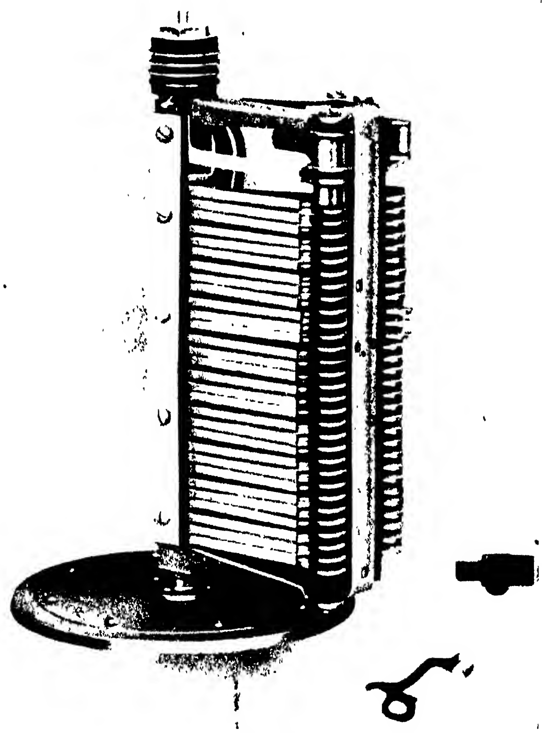


FIG. 91. ROTARY SYSTEM SELECTOR BRUSH CARRIAGE AND BRUSH.

The Operation of a Group Selector.—This switch automatically connects a calling junction to an idle junction in a group leading to another switching stage. The trip spindle is moved under the control of the register and, for each impulse received, sends back to the register one impulse until the latter reaches zero. If four impulses have been sent, the fourth tooth is left in position to unlatch a brush. The power magnet of the carriage then comes into operation. As the brushes pass the trip spindle, that set corresponding to the tooth in the path is unlatched, so that the three brushes make contact with set after set of terminals until an idle line is found. Current is then cut off the power magnet, but the brushes are not stopped until the earthing top arm has properly centred the brushes on the terminals. The spindle magnet has meantime been energised to rotate the trip spindle through the remainder of the circle to normal, when a deeper notch in the power cam allows the power circuit to be

opened. When the connection is released, power is applied to the carriage magnet so that the brushes are carried over the remainder of the terminal arc, when the projecting brushes are forced back to their normal position as they pass over the roller. The carriage continues to rotate until normal is reached, when contact is made by the top earthing arm with a bracket piece placed near the top of the trip spindle.

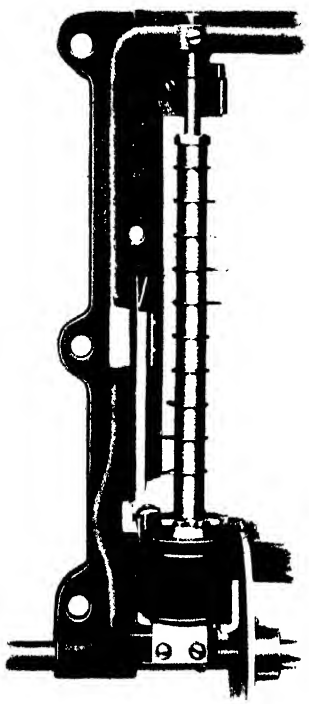


FIG. 92. ROTARY SYSTEM SELECTOR BRUSH CHOOSER.

The Final Switch.—This is practically similar to the selector. There is, however, a local contact, which is operated by the toothed rack, which sends back one impulse for each one received from the register until zero is reached; each terminal passed operates the local contact, which operations are counted off by the register. This is necessary because a predetermined terminal must be reached to connect with a particular subscriber. When the desired number of steps have been taken the register cuts off the power and the brush carriage comes to rest. As each final switch connects with 200 lines, the terminals are arranged in 10 sets of three vertically, and with 20 terminals in the arc.

The advantages claimed for this construction are as follows:—

The massive build ensures stability of alignment of parts and thus avoids any change in the interaction of parts.

All wear is automatically adjusted so that neither adjusting springs, cams nor screws of any kind are provided.

Ten sets of brushes instead of one set simplifies the mechanism and avoids the sliding vertical moving, which prevents exact alignment of the brushes relatively to the terminal levels

All parts are readily removable for repairs.

The complete revolution of the brushes simplifies continuous hunting for an idle line.

The commutator rings eliminate flexible cords.

The surfaces of the terminals are arranged vertically so that there is little surface on which dust can collect.

The use of bronze terminals with the long grain to the brushes secures freedom from wear and ensures a contact of low resistance.

All contacts are equally cleaned, as the brushes make a complete revolution. All are worn equally.

The use of power driven parts ensures firm contacts.

Section 40

W. E. CO.'S ROTARY SYSTEM. AUXILIARY SWITCHES

The Sequence Switch (Fig. 93).—A sequence switch is also shown in Fig. 88, fitted alongside the selector switch with which it is to co-operate. The switch is mounted in a frame in which the spindle is pivoted. The frame carries a plate on which the lever or moving springs and left and right contact springs are fitted. The lever springs may make contact with either the left or right springs, or may occupy a central position free from either. These movements are controlled by ebonite cams which are threaded on a vertical spindle, and are rigidly secured thereto so that they rotate with it. The upper separate cam on the right shows how these are cut with hollows and raised surfaces so that the lever spring may take up one or other of three positions in a revolution of the cam. Above these cams is a disc numbered from 1 to 18 (the number of positions the spindle may take up), and the drooping index finger indicates in what position the switch is in at any moment. There are 18 cams in three sets of six. Below these is a power cam which controls a spring to open and close the power magnet local circuit. This spring carries a roller, which rides over the surface of the power cam. Such a cam is shown detached, to the right and bottom of the picture. Below this cam is the power magnet with the magnetic clutch. The iron disc is above the coil, and the diaphragmed ring, to be brought into engagement with this, is fixed to the power spindle.

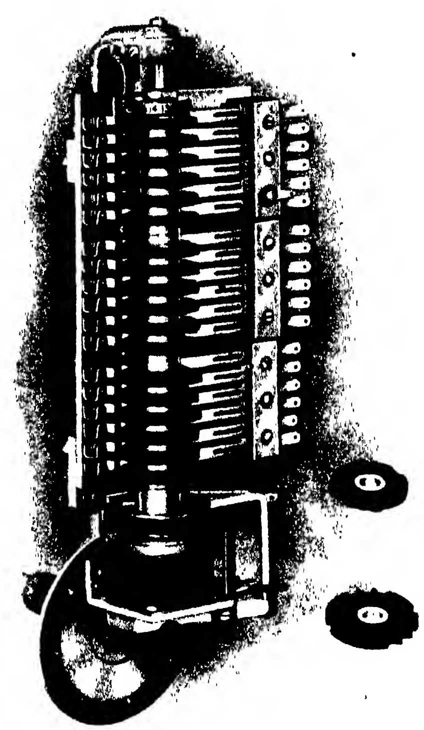


FIG. 93. ROTARY SYSTEM SEQUENCE SWITCH.

Operation of the Sequence Switch.—The spindle stands normally in position 1, in which the lever springs may be in any of the three positions indicated. When the circuits are to be changed current is sent through the electro-magnet, and the magnetic circuit thereby completed to rotate the disc and spindle. When rotation commences, the power local circuit is closed and maintains the magnet energised. The spindle will continue to move until the local circuit spring falls into a notch on the power cam, when the circuit will be opened to stop the switch. During this movement certain contacts have been opened and closed to bring about a different combination of circuits and apparatus. This movement is repeated when the magnet is again energised, so that the circuits are opened and closed in a predetermined sequence.

Particular features of the sequence switch are :—

The contacts are very firm. Unchanging alignment is maintained.

No current is required to hold the contacts closed.

A contact may be opened and closed repeatedly during a revolution, and therefore a relay, for example, may be connected in different circuits.

The speed being uniform contacts of definite duration may be made.

A contact may be closed before or after another, as required.

By undoing one screw a spindle may be readily replaced.

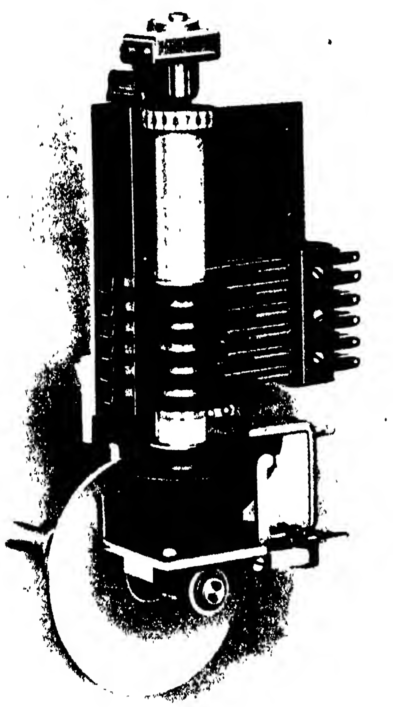


FIG. 94. ROTARY SYSTEM REGISTER.

The numbered disc and pointer indicate the position of the spindle instantly, and this is most useful if anything goes wrong.

The contacts are arranged vertically, and are of platinum.

The sequence switch used in connection with the call-finder switches is very similar to that described, the principal difference being that these have 12 cams only, arranged in two sets of six.

The Register (Fig. 94).—As will be seen from the illustration, this resembles very closely the sequence switch. The principal difference lies in the arrangement of the cams and contacts. It has 20 positions, but a cycle of operations is performed in 10 positions, or in one half revolution.

The digit sent in by the subscriber is said to be registered when the spindle turns through a number of positions equal to the number of impulses sent in. In the full automatic system this is usually complementary to the digit, in which 10 steps are taken for digit 0, nine steps for digit 1, and so on, so that the spindle in moving forward to normal through the remaining positions will send out a number of impulses equal to the digit of the directory number.

The means employed by the register for translating impulses is described in Section 42.

The selecting relay used in connection with the register is shown in Fig. 95. This is also used in other circuits where its permanency of adjustment secures accurate and reliable working.

The register is the all important controlling feature in the machine switching system. It receives the impulses sent out by the dial, translates them, and sends them to the switches in the manner best suited for their efficient operation. It does not wait until the impulses of all the digits have been received, but may send them out as soon as one set has been received. It waits until the switch at the other end of the selected trunk is ready, and then sends out the next set and so on. If all trunks in a group are busy, it will wait while the switch continues to hunt, and when a line and switch are found, will then control. Calls are thus delayed only and not lost. The register is thus very suitable for hunting over very

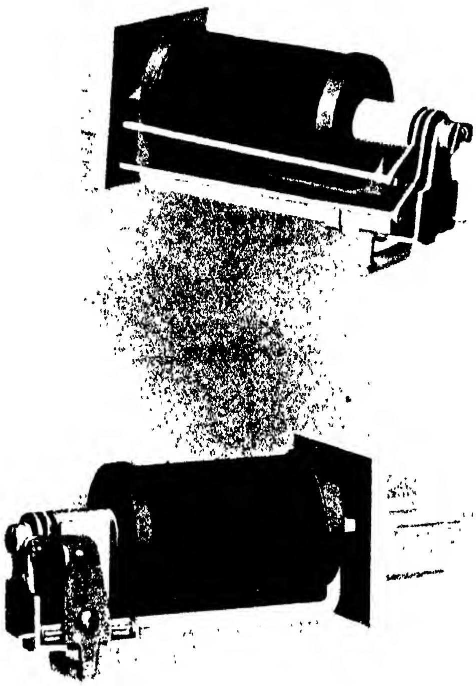


FIG. 95. W. E. CO.'S RELAY.

large groups of trunks. The switches can be very robustly built, they can be operated at their best speed, and are independent of the speed of the dial-senders as regards rapidity of impulses or intervals between digits.

Section 41

ASSEMBLY AND CABLING

Fig. 85 shows the general arrangement of apparatus in a small installation. To the left are the line switches with their sequence switches in a vertical panel, then group selectors with their sequence switches in an adjacent vertical panel, then the final switches with their sequence switches, then auxiliary sequence switches and registers. Fig. 96 shows a front and back view of one bay or panel, strongly constructed of angle iron fastened top and bottom to castings so as to be very rigid. The terminal plates, appertaining to the same lines, are

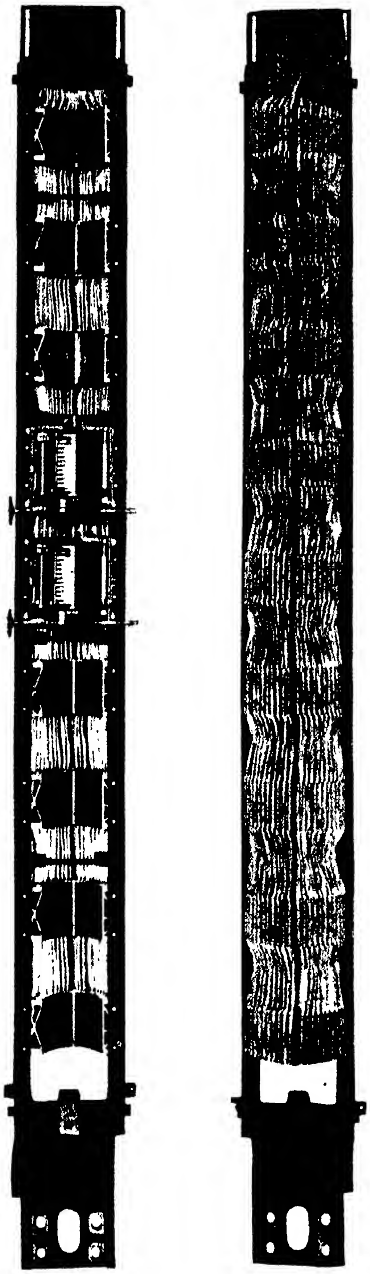


FIG. 96.—W. E. CO.'S ROTARY SYSTEM. FRONT AND REAR VIEWS OF A BAY OF SELECTORS.

thus arranged vertically one above the other, and are multipled together with a special ribbon cable. This cable is shown more in detail in Fig. 90. The cable consists of 30 wires laid side by side, and held together by weaving, so that the wires are insulated from each other. The weaving, which is done in a loom, exposes the wires in such a way that a diagonal line of bare patches is across the cable at set intervals. Before being placed in position the cables are bent on the line of the bare patches, so that when the cable is placed against the terminals as shown, the bare patches coincide with the terminals, and these by a simple soldering process are connected together. Each soldered terminal remains clearly visible, and accessible for maintenance and repairs without disturbing the multiple The upper ends of the cables are connected to soldering tabs which are fitted in a rack at the top of each bay. These connecting racks are multipled across from bay to bay for the entire group.

Owing to the low capacity between conductors, the wires can be placed side by side without twisting, without introducing cross talk. When connecting up a considerable number of machines, the wires of the cable can be connected in transposed relationship by means of the connecting rack at the top which eliminates any cross talk.

Section 42

FUNDAMENTAL FEATURES OF THE WESTERN ELECTRIC CO.'S ROTARY SYSTEM

Translation.—A 200-line switch was adopted as the standard, because careful study, involving the balancing of the decreasing number of switches against increasing cost per switch, showed that this capacity was near the economical point for the particular selector type, on the basis of present apparatus design, knowledge, and practical manufacturing possibilities.

It then followed that the impulses on the 10 by 10 basis sent out by the dial were no longer directly able to control the arm of a final 200-line switch, and set the wipers on the line wanted Some piece of apparatus is therefore necessary to convert the impulses sent in on a decimal basis into a series of impulses on a basis corresponding to the grouping of the terminals. The *register* performs this function among others.

Principles underlying the Process of Translation. A subscriber in sending a number produces, by his impulse sender, a series of impulses corresponding to the digits of

B																				
1	111	112	113	114	115	116	117	118	119	110	211	212	213	214	215	216	217	218	219	210
2	121	122	123	124	125	126	127	128	129	120	221	222	223	224	225	226	227	228	229	220
3	131	132	133	134	135	136	137	138	139	130	231	232	233	234	235	236	237	238	239	230
4.	141	142	143	144	145	146	147	148	149	140	241	242	243	244	245	246	247	248	249	240
5	151	152	153	154	155	156	157	158	159	150	251	252	253	254	255	256	257	258	259	250
6	161	162	163	164	165	166	167	168	169	160	261	262	263	264	265	266	267	268	269	260
7	171	172	173	174	175	176	177	178	179	170	271	272	273	274	275	276	277	278	279	270
8	181	182	183	184	185	186	187	188	189	180	281	282	283	284	285	286	287	288	289	280
9	191	192	193	194	195	196	197	198	199	190	291	292	293	294	295	296	297	298	299	290
10	101	102	103	104	105	106	107	108	109	100	201	202	203	204	205	206	207	208	209	200

FIG. 97. NUMERICAL WIRING OF SELECTOR BANKS.

the number wanted, 0 digit representing 10 impulses. There is another impulse scheme in which digit 0 is sent by one impulse.

When the register is described as sending out impulses to control switches, it is to be remembered that this is not what actually happens. The register sends out impulses to the switch, which sends back impulses which are measured off by the register on the *reverse impulse control* basis.

Fig. 97 shows a method of numbering the banks of a 200-line final switch, and Fig. 98 the wiring from the group selector. It will be at once realised that direct decimal calling, as on the Strowger system, is not suitable for connecting in such a bank. A different method of directing the wipers must be adopted. *Translation* is necessary.

To avoid confusion, certain new terms have been adopted by the W. E. Co. The train of impulses sent out *last* by a set of registers is known as the *a* place, those sent out immediately before the last the *b* place, and those sent out just before these two the *c* place, these corresponding to the units, tens, and hundreds in the decimal system. The *a* place impulses direct the brush of the final switch, and are always equal to the digit received in the units place, except that 10 additional impulses must be added when the hundreds are even, *e.g.*, No. 196 requires six impulses in the proper level, but 296 requires 16 impulses to carry the

brushes to that number. The *register* determines whether the hundreds digit is odd or even, and if even, it must send out 10 additional impulses in the *a* place.

The train of impulses sent out in the *b* place is always equal to the digit in the tens place of the number wanted. This brush-selecting train trips the brush associated with the correct level. If 196 is called, nine impulses in the *b* place would trip the ninth brush associated with the ninth level.

The train of impulses sent out in the *c* place is made up in a special way. On referring to C, Fig. 98, it will be seen that there are 10 levels of a group switch on the left, the associated brushes of which are to be directed by the impulses of the *c* place to one of the 10 levels. These 10 levels are connected by trunk with 10 final switches at the right, having terminals numbered in the units and tens places, like B. It is assumed that the capacity is 2,000 lines (Nos. 1,000 to 2,999).

1. The odd numbered levels have access to the odd numbered hundreds of the same magnitude when the thousands are odd. To call 1,396, three impulses (equal to the hundreds digit) are sent to the *c* place.

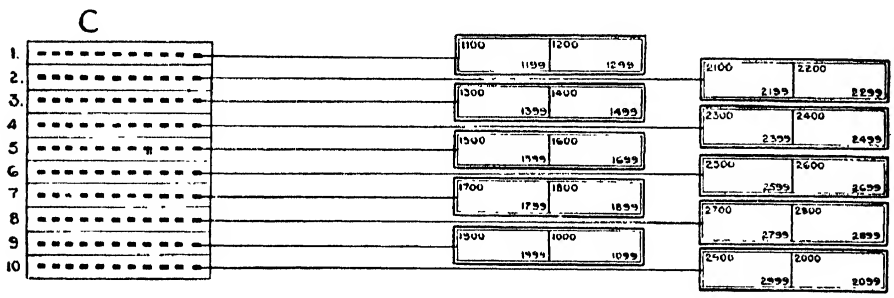


FIG. 98.—WIRING FROM THE GROUP SELECTORS.

2. The odd numbered levels have also access to the next higher (even) hundreds. To call 1,496, three impulses (equal to the hundreds digit 4 — 1 = 3, when the hundreds are even) must be sent in the *c* place.

3. The even numbered levels have access to the same odd hundreds as those of the previous level, but in the next even thousands. To call 2,396, four impulses (equal to the hundreds digit 3 + 1 = 4, as the thousands are even) must be sent in the *c* place.

4. These even numbered levels also have access to the next higher (even) hundreds in the same thousands. To call 2,496, four impulses (equal to the hundreds digit 4 — 1 = 3, as the hundreds are even, and plus 1 = 4, as the thousands are even) are sent in the *c* place.

It follows from the above that the train of impulses sent out in the *c* place is always equal to the digit in the hundreds place in the number called, except that one impulse is deducted when the hundreds are even, and one impulse added when the thousands are even.

The train of impulses sent out in the *d* place is made up like that of the *c* place; the principle being to send impulses equal to the original thousands digit received, minus one if this be even, and plus one if the ten thousands digit received be even.

Similarly the train of impulses sent out in the *e* place is made up by taking the digit in the ten thousands place, and modifying it, as described, for the *d* place.

There are other ways possible for numbering the 200-line terminals of a final switch, as also for connecting the levels in a group switch.

It has been found preferable at times to place 0 at the beginning of the digit series as on the complementary basis, when for digit 0 the dial sends 10 impulses, and the register allows one impulse to be taken out, and for digit 9 the dial sends out one impulse and the register allows 10 to be taken out.

Section 43

REVERTIVE IMPULSE CONTROL

This, also, is an essential feature of the system. Selection is performed by closing the line circuit at the sending end, to cause the distant selecting brush to revolve, and make contact with terminal after terminal. For each terminal so made contact with an impulse is sent back to the sender, to cause it to take one step towards normal. When normal is reached the line circuit is opened, and the selector brush carriage stops. If the sender had to take six steps to reach normal the brush of the selector would be on the sixth terminal.

Fig. 99 is a simplified diagrammatic circuit. At the sending end A is a register spindle, driven by a magnet RU, which attracts the spindle disc S2 to the continuously rotating shaft disc S1 when energised, to cause the spindle to rotate. The spindle arm S3 can be displaced from normal any number of steps up to ten. In the 0 position a circuit is completed for relay AR. The differential relay D'R prevents the spindle taking more than one step when moved.

At the receiving end B is a selector, with brush carriage, which carries a brush B14, to make intermittent contact with the earthed tooth rack A4. The teeth are in the spaces between terminals, so that the brush B14 is earthed when the line brushes are between two sets of terminals.

The sender and receiving apparatus are connected by what is known as a fundamental circuit, which always has at the sender end a relay SR', the back contact of the relay AR and a spring F to close the circuit when selection is to begin. At the other end is always a relay FLR, and a battery.

We will assume that the selector is to make contact with the sixth set of terminals. The arm S3 is set to position 6.

1. When the contact F is closed the fundamental circuit is completed, and relays SR' and FLR are energised, when selection begins. At the same time two springs (not shown) close the differential circuits of relay D'R, the left hand winding being closed before contact F.

2. The magnet P' is energised over the front contact of FLR, until the sixth set of terminals is reached. The brush carriage is thus rotated. The brushes A', B', C' make contact successively with sets of terminals in a level, while the brush B14 is earthed successively in the spaces between terminals.

3. Before the line brushes reach the first set of terminals B14 touches an earthed tooth, and short circuits the relay SR', so that it de-energises.

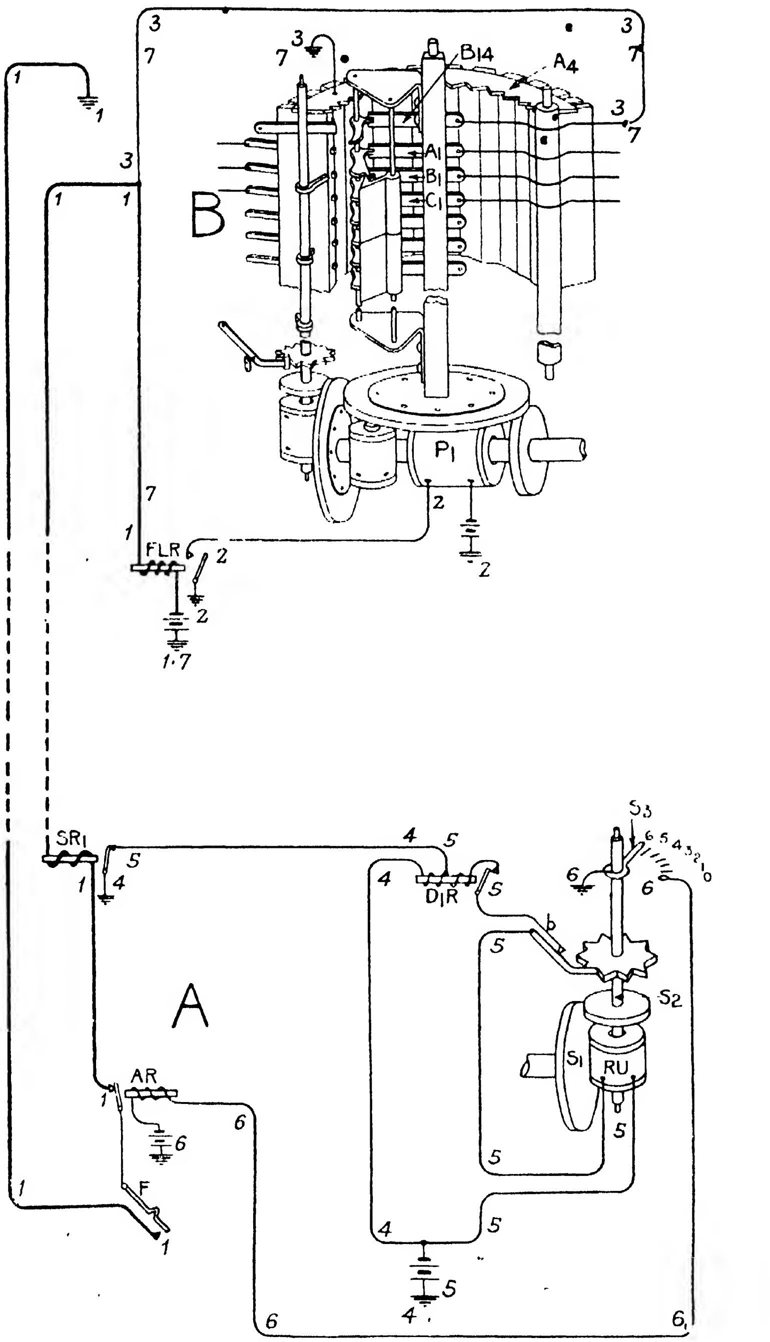


FIG. 99.—W. E. CO.'S ROTARY SYSTEM. REVERTIVE IMPULSE CONTROL.

4. 5. The magnet RU is energised over contact *b*, one winding of D'R and back contact of SR'. A circuit is also completed over the second winding of D'R. The currents in the two windings neutralise each other so that the relay is not energised. The spindle is set in motion and, as S3 moves from position 6 to 5, contact *b* is opened and D'R energises. The circuit of magnet RU is opened and the spindle stops, with S3 centred in position 5. Contact *b* is then again closed.

When the line brushes reach the first set of terminals, B14 is again insulated, and SR' again energised. Circuits 4 and 5 are opened and D'R de-energises. Between the first and second sets of terminals brush B14 is again earthed, so that SR' de-energises, the magnet RU is energised, *b* contact is opened and D'R is energised over one winding, S3 is rotated to contact 4, and the *b* contact is again closed. Thus the spindle steps until the 0 terminal is reached.

6. Relay AR energises over terminal 0, S3 and earth. The fundamental circuit 1 is opened and SR' de-energises, to begin the stopping of the brush carriage.

7. Relay FLR remains energised over B14 and A4, until the brushes are centred on the terminals, when B14 will be insulated. FLR then de-energises to open circuit 2, when the power magnet P' de-energises to stop the brush carriage.

The line brushes are now on the sixth set of terminals, the register is on 0 and the fundamental circuit open.

The advantages claimed for reverse impulse control are :—

The circuit is metallic without earth at the sending end.

The sender does not take its next step until the brush takes its next step, so that, if the brush is slow, the sender will wait.

The impulses that perform the selecting are sent back by the switch towards the sender. No step, therefore, can be lost, due to the sender mechanism being light while the brush carriage is heavy. Firm contacts are made.

The brush carriage is not stopped until it has reached the terminals wanted, even though the light controlling mechanism has opened the fundamental circuit.

It permits the application of power drive in a simple effective manner to move the relatively heavy brush carriage.

Section 44

TYPICAL EXPLANATORY CIRCUITS. A LINE FINDER CONNECTING WITH A CALLING LINE (Fig. 100)

The circuits, in the order of operation, are as follows :

1. Receiver lifted to call, relay LR energised.
2. Relay CR energises and starts a group of call-finders hunting
3. Relay GLR energised.
4. Clutch magnet PF energises to rotate brushes.
5. Brush H6 first touches toothed rack H5 to short circuit GT2R, over spring N.

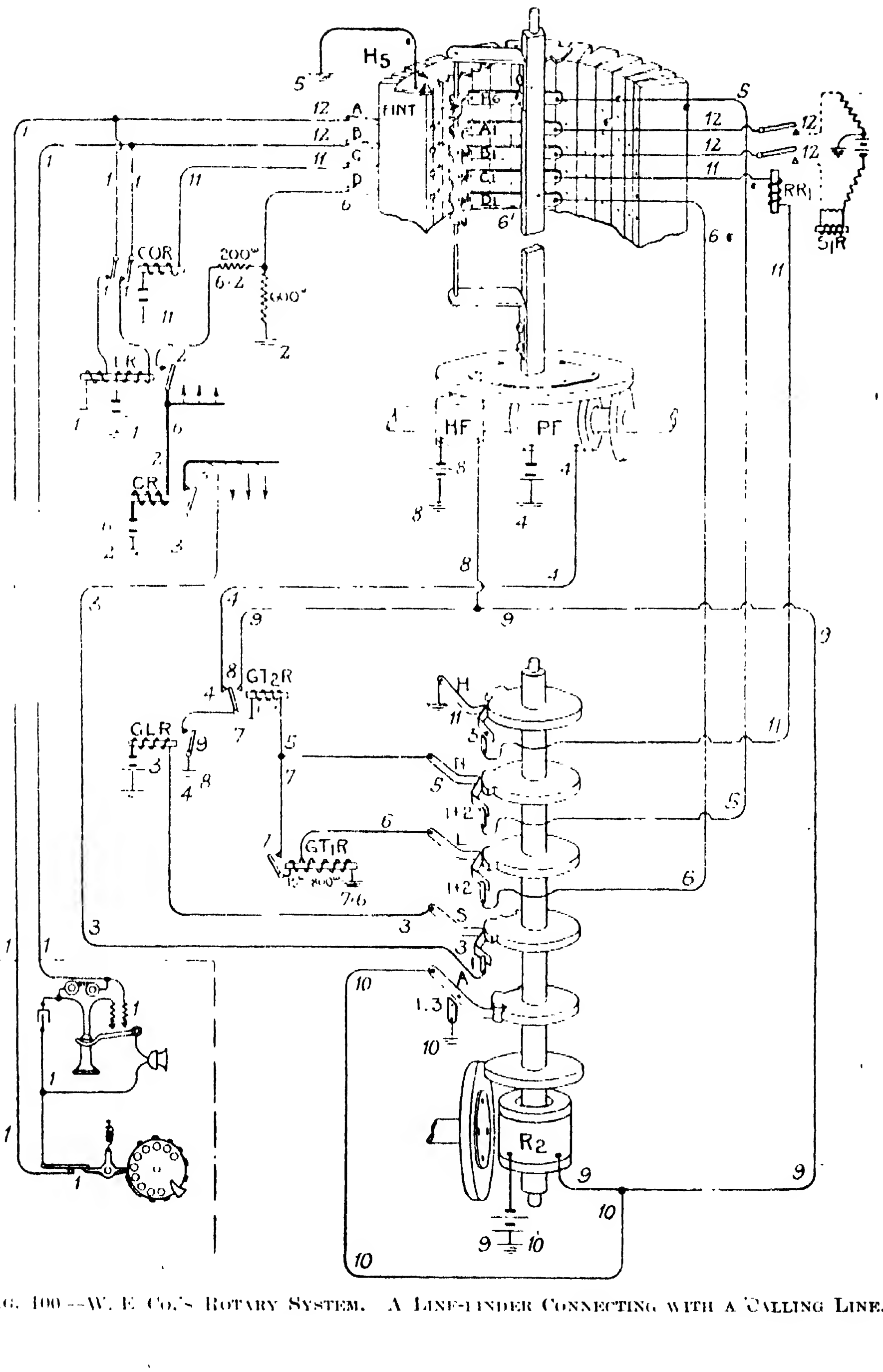


FIG. 100.—W. E. Co.'s Rotary System. A Line-finder Connecting with a Calling Line.

The function of this brush is to centre the brushes fairly on the contacts, and this is attained when H6 is not making contact with the rack, but standing midway between the teeth, when the short-circuit on GT2R is removed.

The non-calling lines test terminals are normally earthed through 600 ohms, and the brush D1 is also earthed through the 800-ohm winding of GT1R; the test terminal of the calling line, however, has been connected to battery, through CR and 200 ohms resistance (shunted by 600 ohms), so that the voltage is about 36.

6. As the brushes of a plurality of finders are rotated, one will make contact first with the test terminal of the calling line, when a circuit will be completed through the test terminal D and the brush D1.

7. GT1R energises and completes a parallel circuit, of low resistance, through GT2R.

Any other finder brush D1 touching the calling line test terminal will fail to energise its GT1R relay owing to circuit 7.

8. GT2R energising opens circuit 4 to de-energise PF, and completes a circuit for the holding magnet HF, so that the brushes are stopped instantly.

9. Sequence switch R2 is energised over front contacts of GT2R and GLR, to cause it to step to another position, to build up the next combination of circuits.

10. The sequence switch R2 steps from position 1 to 3, by a local circuit over spring A. This switch may take one step because of a circuit completed outside the switch, or be started by such, and continue to rotate a predetermined distance by the circuit over the spring A, until stopped by a spring dropping into a notch on a cam star wheel.

11. In the third position of the sequence switch a circuit is completed for the relay COR over terminal C, brush C' and spring H. In this is relay RR1 which energises. Relay COR energising cuts off relay LR, and circuit 2 is opened to de-energise CR, so that other finder switches stop hunting.

12. The loop 1 is extended to the next stage, as indicated by repeater and relay S1R.

Section 45

CALLING LINE CONNECTED TO AN IDLE REGISTER (Fig. 101)

A plurality of preselector circuits has access to any one of six registers. A sequence switch R3 is associated with each such circuit for testing purposes, and begins to rotate when a finder switch connects with a calling line.

The circuits in the order of operation are as follows:—

1. A line has been extended, as previously described (Fig. 100), and sequence switch R2 energises, and in position 3 closes contact F.

2. Sequence switch R3 then energises over contact F and back contact of relay GT2R. Whilst spindle of R3 rotates it tests the six registers by successively closing the six contacts of C, D, E, and repeatedly the contact B.

An idle register has its springs K and S closed. Only one register, No. 1, is shown, and with open contacts. Assume the contacts closed.

3. Relay GT1R energises over contacts S, K, E, L, relay GT1R and B contact.

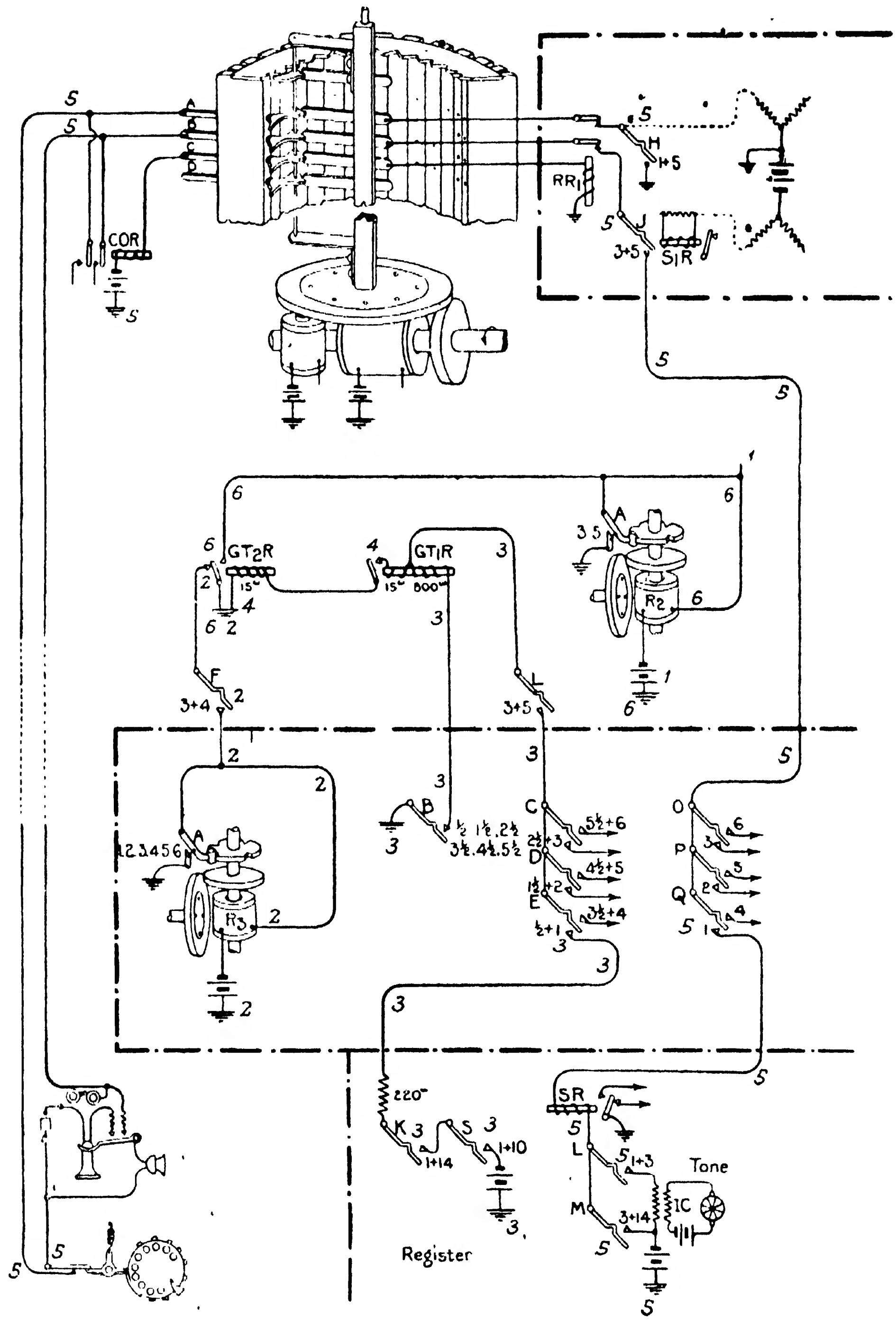


Fig. 101.—W. E. Co.'s Rotary System. A Calling Line Connecting with an Idle Register.

4. Circuit 3 is extended by parallel circuit 4, and relay GT2R energises. Circuit 2 is opened and R3 de-energises. The register is maintained connected to the calling line. The register is made busy by the low resistance of GT1R and GT2R, in parallel with the 800-ohm winding of GT1R.

5. The impulses from the subscriber's dial are received on the selecting relay SR of register, which is now connected over contact Q to the calling line.

6. Sequence switch R2, now having done its work, is driven to position 5 over a circuit completed by the front contact of relay GT2R.

A tone test TC is connected when relay SR energises to advise the calling subscriber that impulses can now be sent. This feature is also useful on extension line working, as it indicates to the extension that the switch at " main " has been set.

It is interesting to note that relays GT1R and GT2R have completed circuits for two functions, thus proving the utility of sequence switches.

Relay RR′ enables a caller to clear promptly at any stage of a connection. On a recall a different finder and register will be picked up.

Section 46

THE SUBSCRIBER DIALS THE NUMBER OF THE DESIRED LINE (Fig. 102)

The impulses are given out on a complementary basis, *i.e.*, for 0 digit 10 impulses, for 1 digit 9 impulses, for 2 digit 8 impulses, and so on, so that the register taking in the former impulses will, by completing its maximum travel, which is 10 steps, send out the difference between the number of impulses received and 10. The impulses are separated by very short interruptions of the line circuit. The first impulse is due to the closing of the line when the receiver is lifted. The long final impulse allows for the changing over from one register to another. In a four-digit exchange there are four registers one for each digit or train of impulses.

The circuits, in the order of operation, are as follows :—

1. Relay RS responds when the receiver is lifted (circuit 6 of Fig. 101). Sequence switch R4 moves to position 2, to connect the magnet RG1000, over spring I, to the receiving circuit.

Relay MR is slow to energise, and energises only when relay SR has de-energised for a predetermined length of time.

The closing of the line circuit also causes the register spindle to be moved one step forward by means of the differential relay DR.

In position 2 of R4 contact N closes to energise relay MR′. A circuit for the differential relay DR is then completed, over the front contact of SR.

2. Over RG1000 magnet, closed contact *b*, contact 2 of I, back contact of DR, windings and battery.

3. Over contact N, winding MR′, back contact of MR.

4. Over front contact of SR, front contact of MR′, winding DR and battery.

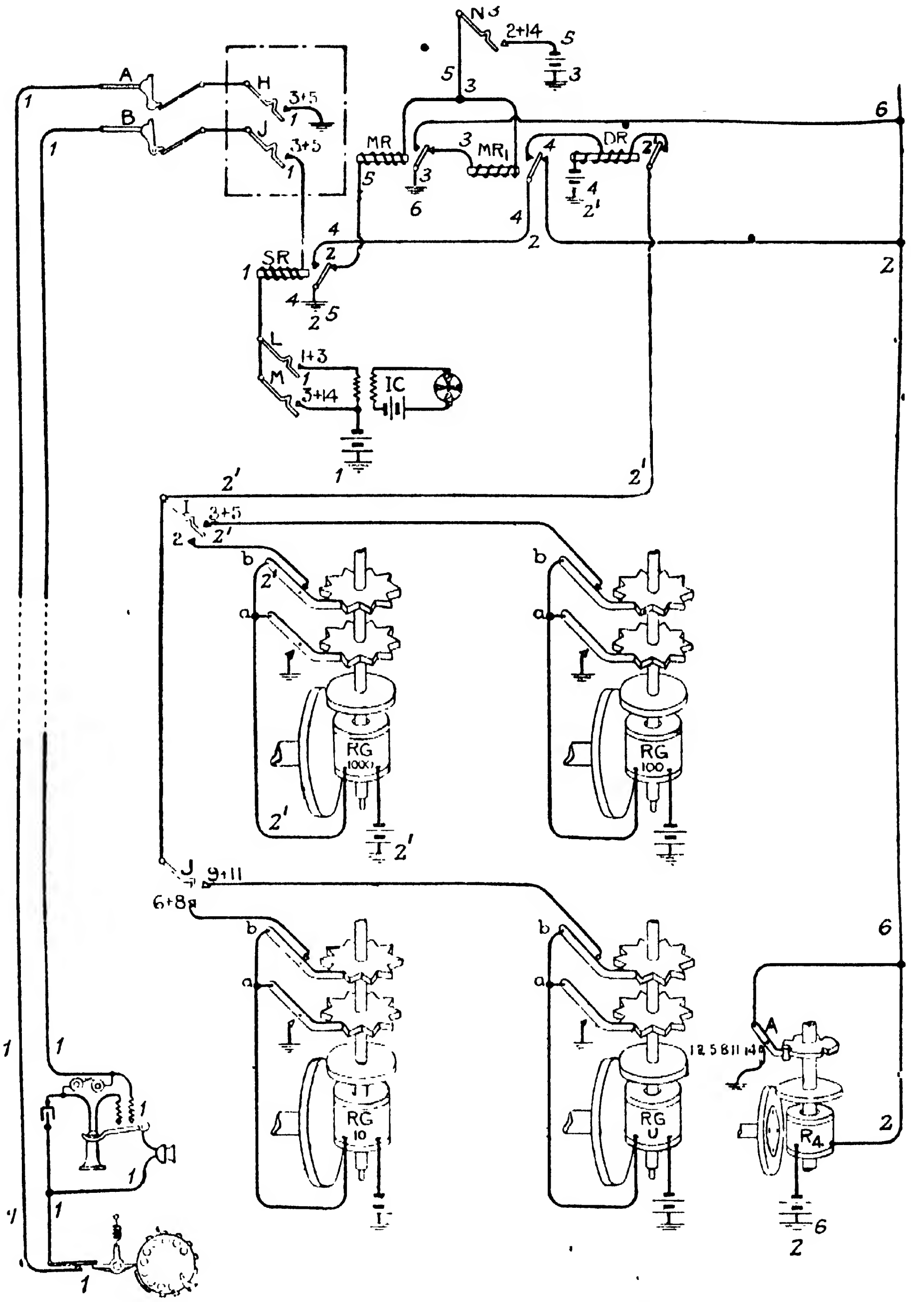


FIG. 102.—W. E. CO.'S ROTARY SYSTEM. A CALLER DIALS THE NUMBER OF THE DESIRED LINE

The currents in circuits 2 and 4 neutralise each other in the windings of relay DR, so that it does not energise. RG1000 is energised in circuit 2, and in moving to position 1 opens contact *b* and, thereby, circuit 2. The current in circuit 4 then energises DR, which also opens the circuit 2′ at the back contact. Relay DR therefore prevents RG1000 from taking more than one step.

The register RG1000 now takes an additional step, for each make after a short break, over the calling line. Each break de energises relay SR, which opens its front contact and allows the differential relay DR to de-energise and circuits 2 and 4 to be re-established. For each impulse, therefore, RG1000 energises, opens the circuit to DR, which again energises, and is again de-energised.

5. During the long final break of a digit's impulses, relay MR energises over back contact of SR and contact N.

Relay MR completes a circuit for sequence switch R4, which moves to position 5, cuts off RG1000 and substitutes RG100 over upper contact 1. The hundreds impulses are now sent in the same manner as the thousands When relay MR energises again after the last impulse of the second digit, R4 moves to position 8, when RG100 is disconnected and replaced by RG10, over spring J in its lower position. The units spindle replaces RG10 in the same way—over J in its upper position.

As each train of impulses is received, sequence switch R4 in going into its next position completes a power circuit (not shown) for another sequence switch R5, belonging to the same register, which controls the sending out of impulses in trains (see Fig. 103).

Should the caller clear prematurely, relay SR will de energise, relay MR energise, and sequence switch R4 will pass through all its positions to normal and break down the connection.

Section 47

BRUSH SPINDLE OF GROUP SWITCH CONTROLLED BY REGISTER (Fig. 103)

The trip spindle of a group switch is advanced a definite number of steps on the reverse impulse method. It must be moved through a definite angle until one of its ten teeth projects into position to release the proper set of brushes Such brushes, when rotated, find an idle line to a final switch.

The circuits in the order of operation are as follows :

1. Relay GLR energises over contact F6 of register, winding SR′, winding GLR and battery.

2. Sequence switch R2 energises to move contacts from position 5 to 6, over contact 5B and front contact GLR.

3. Trip magnet energises to rotate spindle over magnet P2G, contact M6, and front contact of GLR. The motion is continuous, but the spindle is said to *step*.

4. Relay SR′ is shunted by a circuit over contact 6S, INT2 and earth, and SR′ de-energises.

Each time SR′ de-energises it steps the register spindle one step towards normal

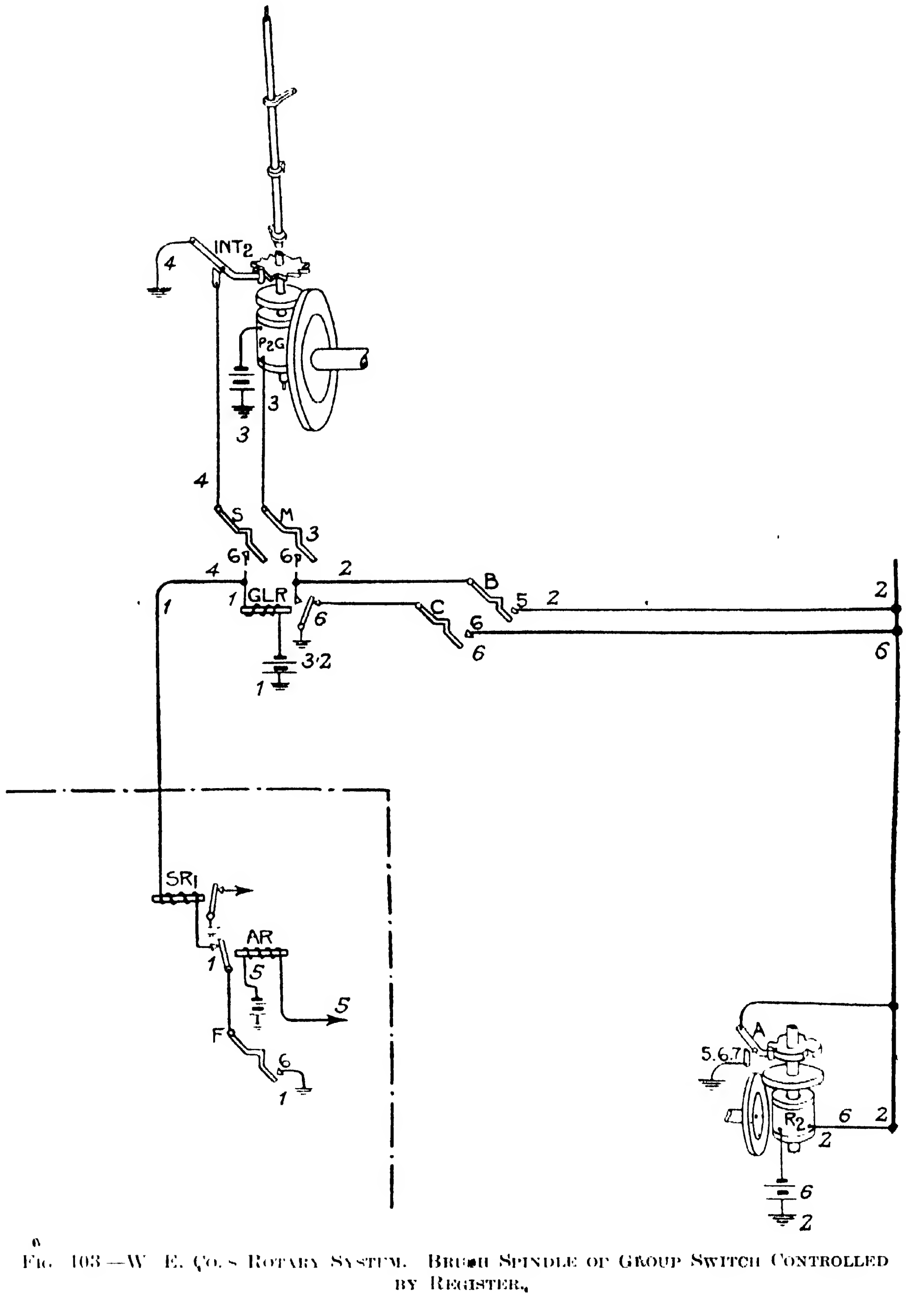


FIG. 103.—W. E. Co.'s Rotary System. Brush Spindle of Group Switch Controlled by Register.

5. When normal is reached relay AR energises, opens the fundamental circuit 1, and GLR de-energises. Circuit 3 is opened. P2G de-energises and stops the spindle rotating.

6. Sequence switch R2 is energised over contact 6C, back contact of GLR, and the sequence switch is moved to position 7.

The trip spindle has taken as many steps, say 5, as are in the register, and a tooth now projects, which releases the fifth set of brushes. These are then caused to sweep over the fifth level of terminals to find an idle trunk to a final switch of the fifth group.

Section 48

REGISTER CONTROLS THE BUILDING UP OF THE DESIRED CONNECTION (Fig. 104)

As described in Fig. 102, the registers were set forward a distance corresponding to the values of the digits of the number called. These same spindles now translate the number, and then direct and control the selectors that establish the connection. Impulses are sent out as soon as each set is received.

As the spindles rotate in one direction only the number of steps required to reach the normal position is the complement of the number of impulses sent in, the spindle having ten positions. Therefore the need for the dial to send out impulses that, when translated, will call the number wanted. The impulse scheme may be shown in tabular form :--

Digit . . .	0	1	2	3	4	5	6	7	8	9
Impulses sent by dial . . .	10	9	8	7	6	5	4	3	2	1
Spindle to normal steps . .	0	1	2	3	4	5	6	7	8	9
Impulse out of relay AR .	1	1	1	1	1	1	1	1	1	1
Impulses out of spindle and AR .	1	2	3	4	5	6	7	8	9	10

The bottom row of figures are the impulses required, each being one greater than the digit wanted.

In a system for 2,000 lines, the 1,000's register spindle is not required in sending, there being only three sets of impulses, those in the *c*, *b* and *a* place, controlled by the 100's, 10's and units register spindle. The 1,000's spindle is only required for translating the impulses in the *c* place.

The electrical operations are as follows. :--

The 100's register spindle is connected to the fundamental circuit, when the sequence switch R5 is moved to position 6. The necessary impulse is sent by sequence switch R4 (Fig. 102), after disconnecting the 100's spindle from the caller's sender circuit.

The trip spindle of the group switch begins to rotate (Fig. 103) as soon as the fundamental circuit is closed at spring F in position 6.

To perform selection the 100's spindle must be set forward one step for each step taken by the trip spindle, as follows. :--

1. The sequence switch R5 in going to position 6 closes spring R in position 2. Battery

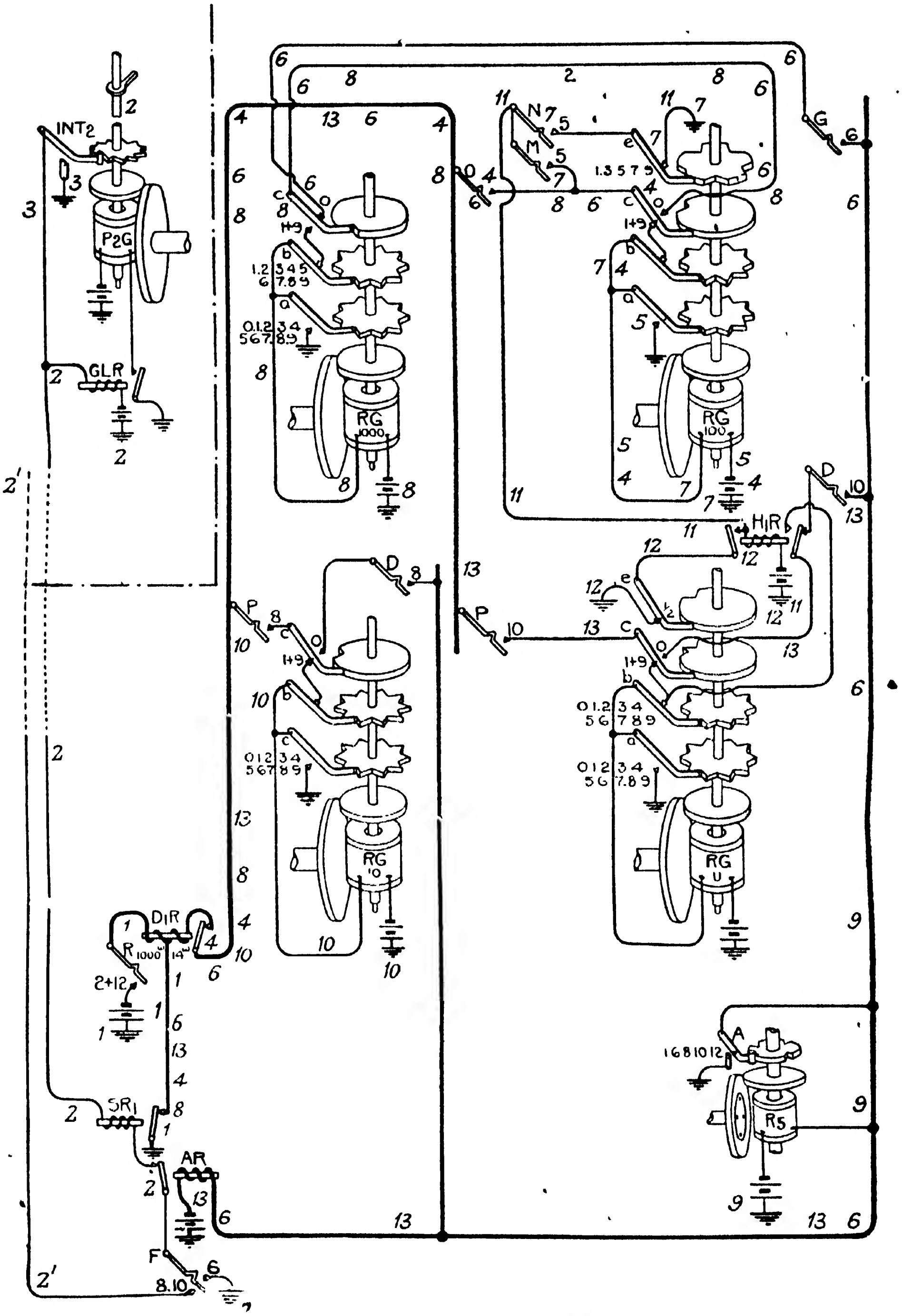


Fig. 104.—W. E. Co.'s Rotary System. The Registers Control the Building Up of the Desired Connection.

is then connected to D1R, which energises and opens the circuit to the SS R5 at its back contact.

2. When the fundamental circuit is completed, through relay SR′ to the distant switch, SR′ energises and opens circuit 1, so that D1R de-energises and again completes its back contact.

3. Before the trip spindle completes the first or any other step it earths the fundamental circuit at INT2, and short circuits SR′, so that it de-energises.

4. Each release of SR′ completes circuits through the two windings of the differential relay D1R, the right hand winding being through the back contact 06, springs *c* and *b* to magnet RG100, and battery; RG100 is energised.

The spindle will take only one step, because a second cam on the 100's spindle, momentarily opens contact *b* as each step is taken, to open circuit 4. D1R now energises, as current is through the left hand winding only. Circuit 4 is open to magnet RG100.

5. A power cam and spring *a* are provided, which completes a local circuit for RG100, which is not opened until the step is completed.

As the trip spindle completes the step, relay SR′ is again energised to open its back contact, when D1R de-energises and re-establishes the differential circuits.

Similar action occurs for each additional step taken, until the 100's spindle is returned to normal, when a third cam operates spring *c*. This permanently opens circuit 4 to RG100.

The trip spindle takes another step, and SR′ is again de-energised.

6. Relay AR energises over contacts 6G, oc of RG1000, oc of RG100, 60, back contact and 14 ohms of relay D1R, back contact of SR′ to earth. The fundamental circuit 2 is opened. This last is the extra impulse taken out of relay AR referred to above.

Translation requires that the series in the *c* place be decreased by one if the hundreds digit be odd, and augmented by one if the thousands digit be odd. An impulse is deducted by simply advancing the spindle one step, before it is connected to the fundamental circuit.

7. On the hundreds spindle there is a fourth cam, having a notch in every second position, and a spring *e* which closes its contact in these odd positions, being those required when an odd hundreds digit is wanted. This contact in closing prepares a circuit to RG100, over the springs M and N, which are closed momentarily in position 5, as the sequence switch R5 passes from 1 to 6. RG100 is energised and takes one step, so that there is now one step less in the spindle to be taken out over the fundamental circuit when the hundreds were odd.

8. An impulse is added by taking an extra impulse out of the thousands spindle. If digit 1 is sent from the dial (for 1,000), *i.e.*, 9 impulses to line, the thousands spindle is moved to position 9. When spring *c* of the hundreds spindle cuts off RG100 after the spindle is returned to normal, it switches into circuit magnet RG1000 over its spring *c*. The selecting relay SR′ taking an impulse out of RG1000, operates an additional time, which returns the thousands spindle to normal, and connects conductor circuits to the cut-off relay AR over circuit 6. The relay SR′, operated for the last time, takes the extra impulse out of relay AR, which energises and opens the fundamental circuit. There is thus added an impulse to the series in the *c* place when the thousands are odd, and only then.

If the capacity is over 2,000 lines, the thousands spindle is controlled by a relay (not shown), so that, when the thousands are odd, the spindle will only go to the ninth position when controlling the impulses in the *d* place. The remaining step is taken as described above by adding an impulse to the *c* place series.

The sequence switch R5, being in parallel with the relay AR, is also operated, and moves its spindle to position 8.

10. The tens spindle is connected to the selecting circuit, over the contact P8, and is ready to measure the impulses for the *b* place. The fundamental circuit is also reclosed at spring F in position 8.

In the meantime, the brush carriage of the group switch has found terminals of an idle junction, and extended the circuit to a final switch, whose brush chooser is placed in circuit relationship with the fundamental circuit.

If the brush carriage is slow in finding an idle junction the tens spindle, connected to the fundamental circuit, is prevented from taking a step by the relay D1R, which remains energised over the back contact of relay SR′, and keeps the circuit open towards the magnet GR10, until the relay SR′ operates with the closing of the fundamental circuit at the distant switch.

The trip spindle of the final switch revolves when the fundamental circuit is closed at both ends and, through the intervention of the relay D1R, steps the tens spindle back to normal. Then one more impulse is taken out, over the cut-off relay AR, which operates, opens the fundamental circuit and stops the brush chooser.

The sequence switch R5, in parallel with relay AR, is also operated and moves to position 10.

The units magnet RGU is now connected to the fundamental circuit, over contact P10, which has again been closed over F, in position 10. In the meantime the brush carriage of the final switch has also been connected to the fundamental circuit and controlled, as described for Fig. 106.

The units spindle RGU is advanced one step for each step taken by the brush carriage of the final switch, and, when returned to normal, connects the relay AR over the spring *c*. The extra impulse is then taken out, energising relay AR, which in turn opens the fundamental circuit and stops the brush carriage.

The operation of translation, when necessary, is simply performed.

It was shown in the section dealing with translation (section 42) that, to reach the proper terminal ten impulses must be added to the series in the *a* place when the hundreds are odd.

11. Relay H1R is energised, over contact N in position 5, and over the spring *e* of the hundreds spindle (closed when the hundreds sent in were odd).

12. Relay H1R is held energised over its front contact, and over the contact *c* on the units spindle, to earth.

Springs *b* and *c* of RGU are connected together over the right hand front contact of relay H1R.

Under this condition, the spring *c* will fail to make the switch-over to the relay AR when the spindle reaches normal the first time, as the relay AR is cut off at the back contact of relay H1R. Therefore the spindle will continue to step, and take ten more steps, until normal is again reached. In taking these steps it passes position ½ when the fourth cam allows the spring *c* to drop into a notch, which momentarily opens circuit 12, and relay H1R de-energises.

13. When reaching the normal position for the second time, the circuit for the RGU magnet is opened, and a circuit for the relay AR completed, over contact 10D, oc, 10P and 14 ohm winding of relay D1R, to earth. When the last impulse is taken out of the relay AR

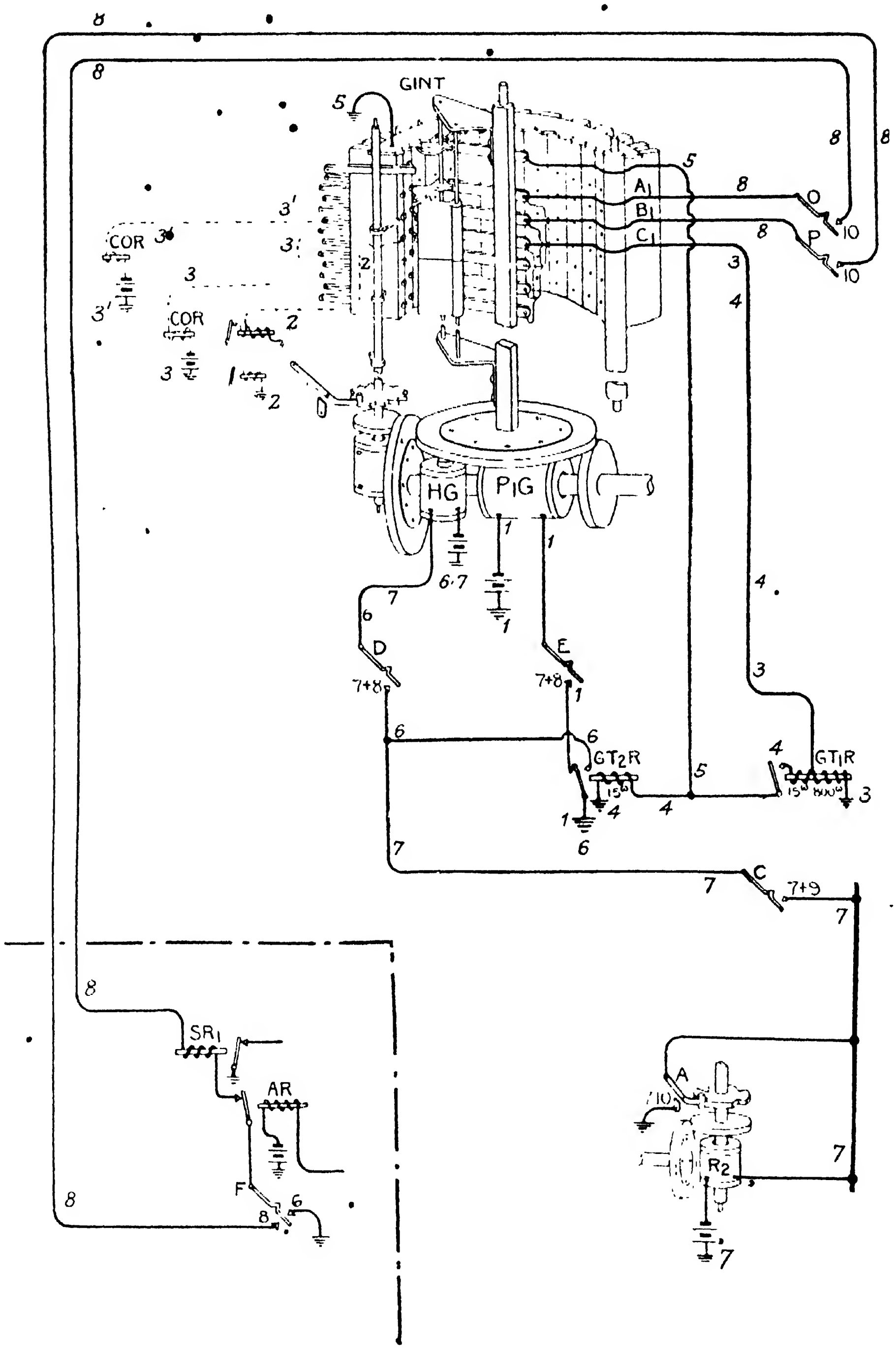


FIG. 105.—W. E. Co.'s Rotary System. Brush Carriage Revolves and Brush Hunts for an Idle Junction.

it is energised, again opens the fundamental circuit, and stops the brush carriage of the final switch.

The sequence switch R5, in parallel with relay AR, is also operated, and moves its spindle into position 12, which initiates the release of the register from the connection circuit (not shown), the register having performed its function.

Section 49

BRUSH CARRIAGE REVOLVES AND THE BRUSHES HUNT FOR AN IDLE JUNCTION

(Fig. 105)

The trip spindle having been advanced a distance corresponding to the digit called, has projected a particular tooth; the brush carriage must then be rotated.

1. When contact E is closed in position 7, the power magnet P'G is energised, and the brush carriage begins to rotate. When the 10 sets of brushes pass the trip spindle, the latch corresponding to the set tooth will be tripped, and the particular set of brushes released. In the figure only two sets are shown, and the top tooth is assumed to be in position to trip the top set of brushes. As the brush carriage revolves, the tripped brushes sweep over the terminals of the level. When an idle line is reached the brush carriage will stop. Each line is tested in passing by the third or test brush touching each test terminal. GT'R and GT2R are the two test relays.

2. A busy line is indicated by the lower terminal third conductor having a parallel path so that there is a potential of only a few volts, and GT'R does not energise

3. The third conductors, above last mentioned, show idle lines, having the relay COR directly connected and therefore, with full battery potential, and relay GT'R energises.

4. The 15-ohm winding of GT'R and GT2R form a low resistance shunt about the 800-ohm winding, to cause the line to test busy to any other switch that may test.

A break or open contact will also cause the line to test busy, when GT'R will not energise.

5. The interrupter, GINT, short-circuits the relay GT'R until the brushes are fairly centred on the terminals.

Relay GT2R energising opens circuit 1 so that the power magnet P'G de-energises to stop the brush carriage.

6. Relay GT2R also closes a circuit for the holding magnet HG, over contact D7, so that the carriage is brought instantly to a stop.

7. The sequence switch R2 is also energised over contact C7, and moves into position 10.

8. The fundamental circuit containing the relay SR' is connected over the contacts O10 and P10, and over the brushes A' and B', to a junction line leading to the final switch.

When the system has a capacity of over 2,000 lines, the fundamental circuit will be connected to a distant second group switch, which will be selectively controlled, as was the first group switch, above described, and which will then extend the fundamental circuit to the final switch, where the terminals of the wanted line are to be found.

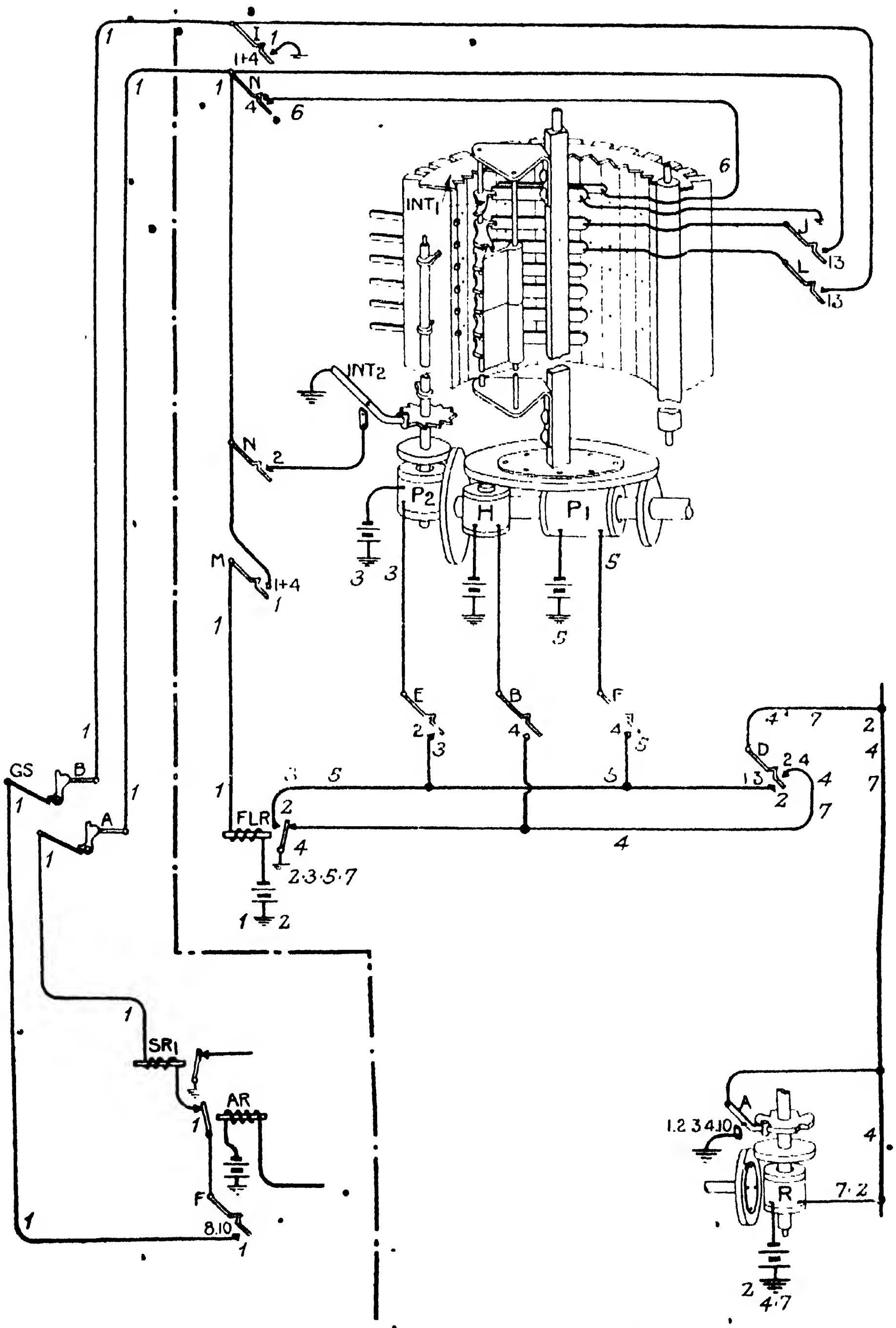


FIG. 106.—W. E. CO.'S ROTARY SYSTEM. BRUSH CHOOSER AND BRUSH CARRIAGE OF A FINAL SWITCH SELECTIVELY CONTROLLED BY THE REGISTER.

Section 50

BRUSH CHOOSER AND BRUSH CARRIAGE OF FINAL SWITCH SELECTIVELY CONTROLLED BY THE REGISTER (Fig. 106)

1. When the fundamental circuit is completed to the final switch, relay FLR energises.

2. Sequence switch R energises, over contact D1 and front contact of FLR, and moves from position 1 to 2, ready to begin the brush choosing operation.

3. Magnet P2 energises over E2 contact and front contact of FLR. The trip spindle of the final switch revolves through a definite angle to set a particular tooth in the path of the brushes. Again each step taken by the brush spindle returns the register spindle a step forwards towards normal. When normal is reached relay AR is energised to open circuit 1, when relay FLR de-energises to stop the spindle.

4. Sequence switch R is energised over contact D2 and back contact of relay FLR.

The register now connects to the units spindle to control the movement of the brush carriage, and again completes circuit 1 by closing contact at spring F. Relay FLR energises and again closes circuit 2. Sequence switch R steps to position 4.

5. Magnet P1 is energised over contact F4 and front contact FLR. The brush carriage begins to rotate, and one set of brushes will be unlatched when the trip spindle tooth is passed. The brush carriage is moved forward and the passage from terminal to terminal is marked off by the interrupter INT'.

6. The fundamental circuit 1 is earthed over contact N4 and INT'. Relay SR' is short-circuited and releases, so that the units register spindle is stepped forward.

The brush is stopped when the register returns to normal by relay AR being energised to open circuit 1, whereby relay FLR is de energised. Circuit 5 is then open and magnet P' de-energised.

7. Sequence switch R is energised over contact D4 and back contact of relay FLR, and steps from position 4 to 10

The line wanted is tested while the sequence switch R is passing from 4 to 10.

Section 51

LINE WANTED IS TESTED, RUNG, AND CONNECTED FOR CONVERSATION; IF BUSY, BUSY TONE IS APPLIED (Fig. 107)

1. The called line is tested when the sequence switch R closes contact G in position 7, over FT'R, brush C", and through relay COR. COR being unshunted, the line tests idle and FT'R energises.

2. A low resistance circuit is completed over the low resistance coil and front contact of FT'R, through relay FT2R, which engages the called line.

3. Sequence switch R is energised over contact C10, front contact of FT2R and back contact of relay FLR. R moves until contact C is opened in position 11, so that R moves to position 12.

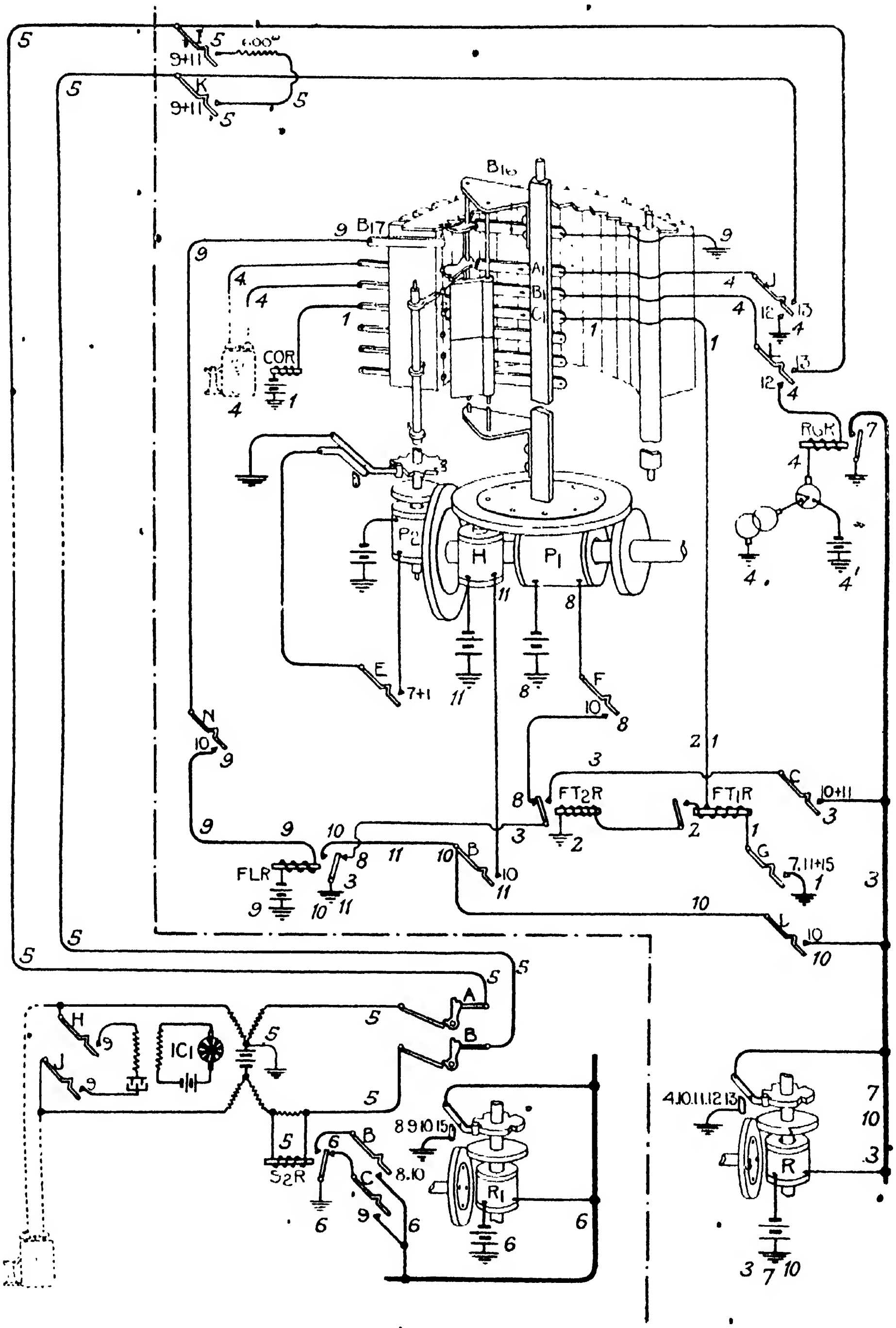


FIG. 107.—W. E. CO.'S ROTARY SYSTEM. LINE WANTED, TESTED, RUNG, AND CONNECTED FOR CONVERSATION, IF BUSY, BUSY TONE IS APPLIED.

4. In position 12 ringing current is sent over relay RGR, contact L12, brush B′, called line, brush A′, contact J12. Battery is shewn applied in intervals of ringing.

5. The calling party is given an indication that the called party is being rung by a short buzz. A 600-ohm bridge is placed across the loop by contacts J and K in positions 9 to 11. The supervisory relay S2R, near the repeater, is energised.

6. The sequence switch R′, associated with the group switch, is energised over contact B8, and is moved to position 9 to connect an interrupter IC′ to the calling line. The bridge is immediately thereafter opened and relay S2R de-energised, when sequence switch R′ is moved to position 10 to cut off the tone.

7. When the called party answers relay RGR is energised. R2 is stepped to position 13 to cut off the ringing current. Relay S2R is again energised, and over circuit 6 energises R1, to move it to position 15, which is the talking position.

If the called line had tested busy, relay FT′R would not energise, nor FT2R, so that the sequence switch would stop in position 10.

8. Magnet P′ is energised over contact F10, back contacts of relays FT2R and FLR, so that the brush carriage of the final switch is revolved towards normal.

9. Relay FLR is energised over contact N10, and the earthed spring B16 touches plate B17. Circuit 8 is opened to de-energise P′, and stops the brush carriage.

10 Sequence switch R is energised over contact D10 and front contact of relay FLR and moves to position 11.

11. The holding magnet H is energised, over contact B10 and front contact of relay FLR. The brush carriage is therefore instantly stopped.

The sequence switch R remains in position 11 until the group switch has released the trunk, when it returns to normal (not shown).

Busy tone is given to the calling party by the interrupter IC″ connected to the line, over the springs H and J in position 9 of the sequence switch R′. It was driven to this position, from 8, by relay S2R over its front contact (circuit 6), S2R being energised in a circuit completed by bridging the 600 ohms resistance on the junction line at the final switch (in position 11 of sequence switch R).

Section 52

CONNECTION IS CLEARED AFTER CONVERSATION (Fig. 108)

When the caller replaces the receiver, the supervisory relay S′R is de-energised.

1. Relay RR energises.

2. Sequence switch R2 is energised, over contact J13 and front contact of relay RR. R2 is moved from position 13 to 18.

3. Circuit 3 is opened at contact K13, and relay QR de-energises, and initiates the return to normal of the final switch.

The return to normal of the final switch will be described, as typical of all the switches.

A test is first made to make sure that the receiver has been replaced. This is necessary to prevent a line with microphone in circuit from engaging another switch and register uselessly.

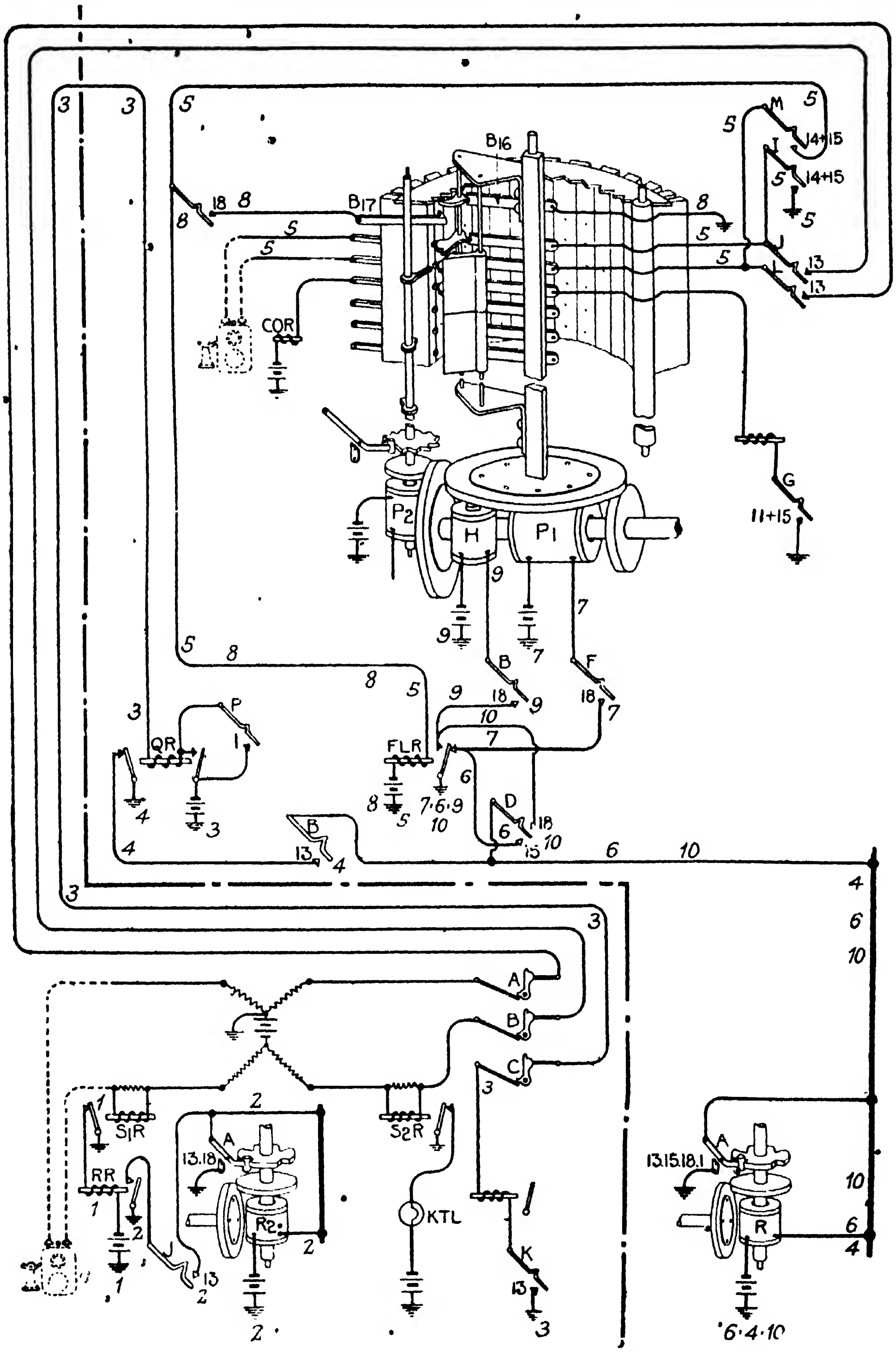


FIG. 108.—W. E. Co.'s Rotary System. A Connection. Cleared after Conversation.

4. When relay QR de-energises, the sequence switch R is energised over contact B13 and the back contact of QR, and moves to position 15.

5. Relay FLR is then connected to the line over contacts M15 and I15. FLR remains energised until the receiver is replaced.

6. Sequence switch R is again energised over contact D15 and back contact of relay FLR, and moves from position 15 to 18.

7. Magnet P′ is energised over contact F18 and back contact of FLR, and the brush carriage is restored to normal.

8. Relay FLR is energised when the spring B16 touches the plate B17, when the brushes reach the normal position over contact 18.

9. Holding magnet H is energised over contact B18 and front contact of relay FLR, to stop the carriage instantly.

10. The sequence switch R is energised over contact D18 and front contact of relay FLR, and moves its spindle to the normal position.

The trip spindle of the brush chooser was returned to normal when the sequence switch R reached position 7, when the circuit of the magnet P2 was closed over the power contact spring engaging the power cam. The trip spindle revolves until normal is reached, where a notch in the power cam is so deep that the contact of the power spring is opened. The power magnet is de-energised and the trip spindle stopped.

Section 53

THE CONNECTION IS REGISTERED AFTER CONVERSATION (Fig. 109)

An effective connection necessitates the advancement of the calling subscriber's meter one step. The registration takes place after conversation, after the receiver is replaced.

When the receiver is replaced, relay S′R de-energises.

1. Relay RR is energised, over contact E15 and back contact of S′R.

2. Sequence switch R is energised, over contact J13.

3. When R2 closes contact I in position 14 sequence switch R′ energises over contact D15. The motion of the two switches will be simultaneous Switch R2 in going from position 13 to 18 passes through positions 14, 15, 16 and 17, while R1 in going from position 15 to 1 passes through 16, 17 and 18.

4. Metering circuit. The special battery is connected over contact Q14 to 17, L16 to 18, brush and terminal C to meter SM. One battery reinforces the other.

Registration cannot take place when the line tests busy or when the called party does not answer. The switch will remain in position 9 or 10 respectively. Under these conditions R2 is moved out of position 13 when the called receiver is replaced, and closes the spring I, as before, to start R′ from position 9 through all the positions to normal. But, as both switches travel at the same speed, R′ will pass through 11, 12, 13, 14, when spring L is not yet closed, while R2 is passing through 14, 15, 16, 17, when spring Q is closed. The meter will not be operated; as the circuit from the battery will not be completed over the springs Q and L, the first closing and opening before the second closes.

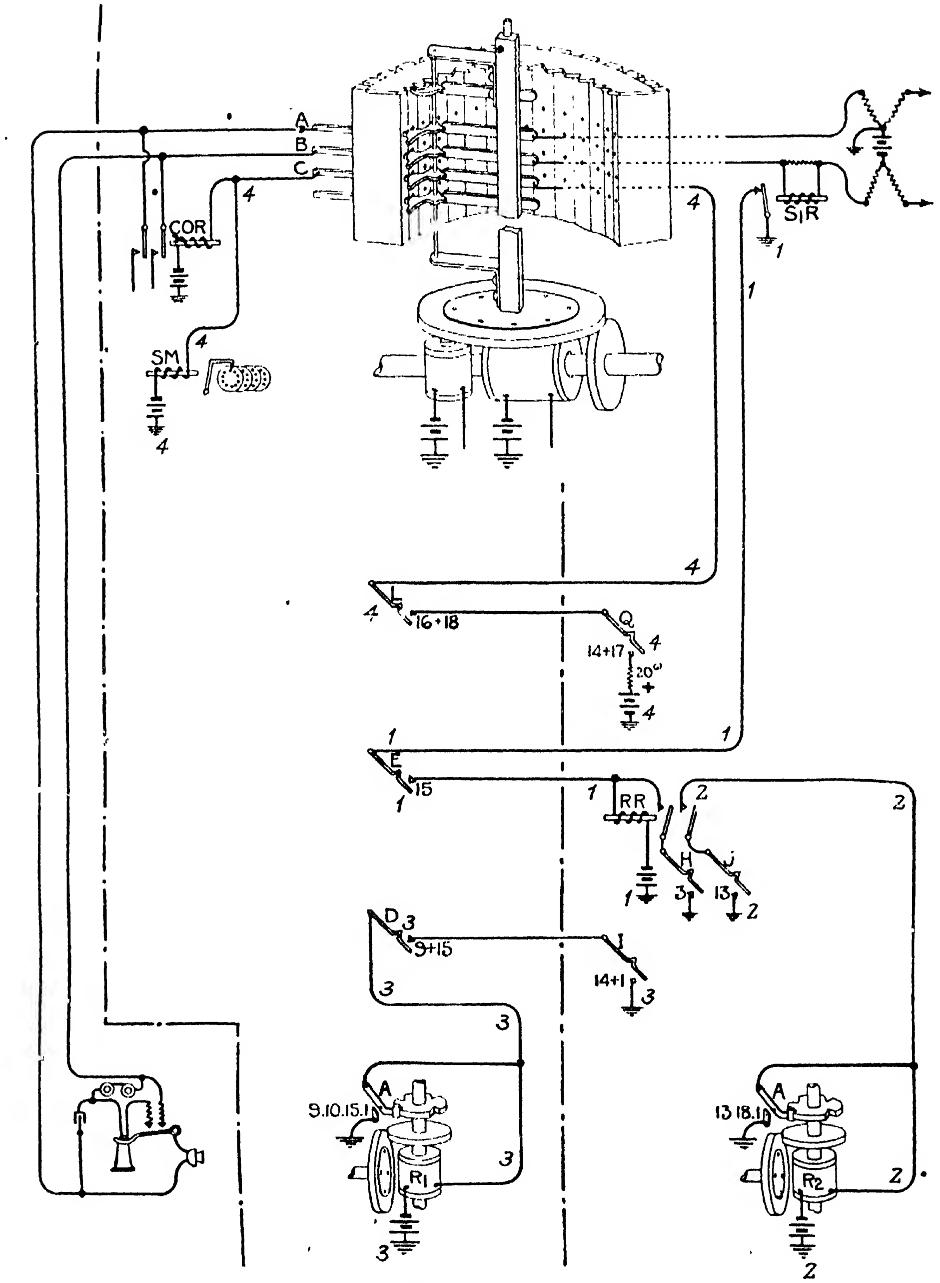


FIG. 1[illegible]9.—W. E. Co.'s Rotary System. A Connection Registered after Conversation.

Section 54

THE REGISTER RECEIVING IMPULSES AND CONTROLLING THE SELECTING OPERATIONS (Fig. 110)

As the diagrams of the commercial circuit (Figs. 115 and 124) appear very complicated, and as it is essential to understand thoroughly the fundamental features of this system an intermediate circuit arrangement follows.

In a register-controller equipment two sequence switches are associated therewith, one establishing the circuits for such register, one after the other, and by which the registers are set, the other sequence switch establishing the circuits, one after the other, by which the registers severally control the necessary and respective selection controlling operations. One sequence switch is known as the *incoming* because it establishes the circuits for the several registers by which they are set, and the other the *outgoing*, because it controls the circuits by which the several registers control the necessary selection controlling operations. These sequence switches are so interdependent that the outgoing switch will only be operated to establish the circuits for the first switch control operations after the necessary setting operations in the registers for producing the proper control in the selectors have been accomplished.

The circuits are numbered in the order of operation, and are as follows :

1. When the receiver is lifted the impulse stepping relay R′ energises.
2. Sequence switch M2 moves from position 1 to 5.
3. SS M2 in position 2, relay R3 is energised.
4. Circuit through left-hand high-resistance winding of differential relay R4.
5. Circuit through low resistance winding of R4, and through magnet M5 of register in series. R4 being differentially wound does not energise. M5 energises and takes one step.
6. Local circuit of M5, to maintain it energised until it reaches its first position. Circuit 5 is then opened at 5′ of register. R4 then energises and opens circuit 5 at its back contact. The contact 5′ is again closed. M5 cannot take a second step until R4 de-energises.

Let the Number to be called be 703. - The first series of impulses, to be received from the dial, are two short ones and one long.

The first interruption of the line circuit causes R′ to de-energise. Circuit 4 is opened, and R4 de-energises. When circuit 1 is again closed M5 energises and moves its contacts to position 2. Circuit 5 is again opened at 5′, and R4 energises over circuit 4.

The second interruption of circuit 1 again causes R′ to de-energise. Circuit 4 is again opened, and R4 de-energises. When the circuit is again closed M5 energises and steps to position 3. Circuit 5 is opened at 5′, and R4 energises over circuit 4.

The third interruption is the relatively long one, to change over the impulse circuit from M5 to the tens register.

7. This circuit is closed for a longer period to allow the slow-to-energise relay R7 to energise (it must not be closed long enough to allow M2 to take more than three steps).

Circuit 3 is open, and R3 de-energises. Circuits 4 and 5 are open, and R4 de-energises.

8. SS M2 energises and moves from position 6 to 8 (provided R7 is de-energised at that time).

Should the subscriber desire to clear at this time the interruption is longer still, and M2 moves through its 14th and comes to rest in its 15th position.

Before M2 arrives in position 8, circuit 1 is again closed, and R′ energises. R7 de-energises and R3 is energised.

9. Circuits 4 and 5 are again completed, but R4 does not energise. Circuit 5 is extended to M9, which moves from position 0 to 1. Contact 9′ is opened, and R4 energises over circuit 4.

Second Digit, 0, impulses.—On the first interruption R′ de-energises and the action is as before, and M9 takes another step. As the second digit is 0, nine short interruptions and one long one will be received. When R′ is energised, between the last short and the long interruption, M9 will take a tenth step, bringing it back to 0 or normal. On the tenth interruption R7 energises, as before, to cause the SS M2 to move from position 8 to 11. In the latter position, the third digit (3), seven impulses are to be received.

10. Register M10 is to be moved seven steps from normal. The last, or long, impulse moves SS M2 from position 11 to 14.

11. When SS M2 moved out of its 5th position it closed, in position 6, a circuit to SS M11, which moved to position 6. The setting of M5 was then completed, and selector controlling begins.

12. SS M11 in position 2 causes the differential relay R12 to energise, through its high resistance, the low resistance circuit being open, and it remains energised until 12′ contact of the outgoing stepping relay is opened.

13. This circuit was prepared previously, and when 13′ contact is closed by M11, in position 6, controlling begins. If circuit 13 is not ready 13′ will close, and the operation be delayed until circuit 13 is completed.

When completely ready, R13 energises in series with the line relay at the selector under control, *e.g.*, relay R17, Fig. 111. Circuit 12 is opened, and R12 de energises.

18. SS M18 energises and moves to position 5. R13 and R17 are maintained energised.

19. Power magnet M19 is energised, and the selector switch moves its brushes Br over the terminals of the group in which the desired line is located, at the same time moving brush BR′ over the interrupter rack INT, so that the circuit is interruptedly connected to earth, first between normal and first terminal, and then between adjacent terminals.

20. Earth over INT maintains R17 energised, but shunts R13 so that it de-energises.

The first de-energisation of R13, due to the shunt on the fundamental circuit as the brush moves from R to 1, closes circuits for the differential windings of R12.

14. Both windings of R12, circuits 12 and 14, receive current, and it does not energise. Register magnet M5 is energised and takes one step to the 4th position. It also closes circuit 6 to enable it to complete the step. Contact 14′ is open, and R12 de-energises. R12 then opens contact 14″, so that M5 takes only one step.

When the shunt circuit has been applied to R13 seven times the register M5 has been stepped seven steps to normal, and the differential relay R12 has been energised and de-energised, as before described.

The stepping magnet R13 is again energised by the opening of the shunt at the brush chooser, and R12 de-energises. As the brush chooser takes its final step R13 is again de-energised and the circuit for R12 closed.

15. The left-hand winding of R12 is now connected to the SS M11 and R15′ in parallel, circuit 13 is opened, thus opening the fundamental circuit, and the selector connects with

an idle line in the group 7. SS M11 moves to position 7 and opens contacts 13′, 15′ and 15″. 13′ opens circuit 13 till the apparatus is ready for a second selecting controlling operation. 15′ and 15″ open the energising circuit of R15′ and M11, and left winding of R12, which energises and remains energised until the second selector and R13 again energise.

SS M11 in its position 7, and the setting of the register M6 being completed, the second selection controlling operations begin. If M7 is not completely set, M11 is maintained in position 7 until the change over from M9 to M10 is completed on the incoming side, due to the long impulse at the end of the second digit. When such is received M2 moves out of position 8 to 11.

16. M2 in position 9, M11 energises and moves into position 8, in which the second selection operation takes place (M2 cannot come into position 9 until M9 is completely set).

The selection controlling is again similar to that described from circuit 11 onwards.

17. As soon, therefore, as the fundamental circuit 13 has been extended by the former operations to circuit 17, or the like of Fig. 111, R13 and R17 energise.

Circuits 18, 19 and 20 operate, as before described.

The digit called being 0, and the register M9 having been moved by the incoming impulses over 10 positions, is, therefore, again in 0.

By the first earthing of INT. R13 is de-energised.

21. Circuit 12 is completed, in parallel with circuit 21, and R12 is not operated. M11 and R15′ are energised in parallel R15′ opens circuit 13, and the brush selecting spindle stops in the first position, to allow of a line being selected in the 0 group. M11 moves to position 9, and the contacts 13, 15′ and 15″ are opened, as when M11 left position 6. R12 is energised over circuit 12.

SS M11 in position 9, and register M10 completely set, the third selecting operations can begin. M2 will only move out of position 11 after M10 is completely set.

22. M11 in 9, and when M2 has left position 11, M11 moves to position 10, and the third selecting operations begin.

The digit to be called is 3, and M10 has been set to position 7 by the incoming impulses. Four impulses have to be received by the switch, and there must be four shuntings of relay R13. When the fundamental circuit 13 is now closed at the final switch, which is to be controlled according to the value of the final digit, R13 and a relay corresponding to R17 are energised

The first shunting of relay R13 will cause M10, as before described, to move to position 8, the second shunting will cause it to move to position 9, and the third will cause it to move to position 0 or normal. The fourth shunting will energise R15′ and the SS M11 in parallel. R15′ opens circuit 13, and the brushes will come to rest on the No. 3 set of terminals of the 0 group, which is the terminal of the subscriber called—703.

M11 moves to its normal position.

23. M2 is moved to its normal position.

All apparatus is now in normal.

Fig. 111 is shown only to indicate the completion of circuits, and does not correspond to the typical circuits previously described, nor to the commercial circuits which follow.

Section 55

A 1,000-LINE ROTARY MACHINE-SWITCHING INSTALLATION (Figs. 112-116)

The numbering is from 1,000 upwards.

A calling subscriber must dial 1 for the thousands digit, but any other digit dialled as a first digit will not bring in the hundreds register, but will connect to an alarm circuit, denoting a wrong number.

The dial is numbered 0 to 9 clockwise. The impulsing is on the complementary basis, *i.e.*, digit 0 sends nine short interruptions and one long one, and so on, till 9 sends no short impulses and one long one.

Every calling line has access to six registers.

The sequence switches are so arranged that only half of a group of second call finders hunt for the calling line. They have two home positions, 1 and 18. When a call finder takes a call, and its register-hunting sequence switch moves, it causes another second call finder to be switched in, so that there is always one half of the group waiting to hunt for a call unless more than one half of the switches are engaged.

On the final switches the even hundred is on the left-hand half and the odd hundred on the right.

On all switches the local A or *a* contacts are open in the positions marked; all other contacts are closed between the positions marked.

The circuits are numbered in the order of operation and are as follows:—

1. When the subscriber lifts his receiver to call relay LR (Fig. 112) energises.
2. Relay GR, common to a group, energises.
3. If all the first line finders are engaged the lamp L3(LGL) glows.
4. If some first line finders are idle the brush carriage magnet M4(P) energises, and all free first line finders hunt for the calling line, and relay R4(LGR) energises. L3 does not glow.

One first line finder connects with the calling line.

5. Relay R5(LT'R) energises in parallel with the 600 ohms resistance.
6. Second winding of relay R5(LT'R) over INT.

Relay R5 is marginal and will not operate when brush D is passing over a busy line.

When the first line finder brush D is fairly centred on the line terminals, INT opens the circuit.

7. Relay R7(LT2R) energises, and, circuit 4 being opened, magnet M4(P) de-energises, and the brushes come to rest.
8. Holding magnet M8(H) and relays R8(GR') energise.
9. If all the second line finders (Fig. 113) are busy lamp L9(GL) glows.
10. If one or more of the second line finders are idle they hunt for the line. Relays R10 and RR10 (GR and GLR) energise. Lamp L9 does not glow.
11. A second line finder brush carriage magnet M11(PF) energises.

The second line finders operate in the same manner as the first. Relay GT'R(R12) functions similarly to R5(LT'R).

12. Relay R12(GT'R) energises.
13. Relay R12 switches in its second circuit, over FINT, until the finder brushes are fairly on the terminals, when FINT opens.

14. Relay R14(GT2R) energises.

15. Sequence switch M15(R′) energises.

16. The second line finder holding magnet M16(HF) energises over circuits 15 and 16.

Circuit 11 is opened at 11′, and relay R14 and magnet M11 de-energise.

Sequence switch R′ moves all associated contacts to position 4. Second line finder holding magnet HF, relays R12(GT′R), R14(GT2R) and RR10(GLR) de-energise.

17. Relays R17(COR), RR17(LH′R), R17′(LCR), energise, but not SM. Relays R′(LR), R2(GR), R4(LCR), R5(LT′R), R7(LT2R) R8(GR′), magnet M8(H), relay R10(GR), and all apparatus of first and second line finders which hunted for this call, de-energise.

18. Relay R18(S′R′) energises over the calling subscriber's loop, while sequence switch M15(R′) is moving over position 2. Relay R18 opens the operating circuit 15, and M15(R′) moves its contacts to position 4.

Sequence switch R′ in position 4.

19. Register finder M19(R3) energises and tests for a free register. Relay R12(GT′R) is now the marginal testing device, and will not operate on a busy register. It functions as it did when testing for the calling line.

Every time M19(R3) passes ½, 1½, 2½, etc., it tests. If we suppose all registers busy until 6½ is reached, then—

20. R12(GT′R) and R20(AMR) energise.

21. Relay R14(GT2R) energises (circuit as 14).

22. Magnet M15(R′) energises and moves out of position 4 to 5, and R20(AMR) sets up—

23. Sequence switch M23(R4) (Fig. 115) energises and moves from position 1 to 3.

Now the B contact of register finder M19(R3) opened in position 7, and sequence switch M15(R′), moving to position 5, opened its contact D: therefore R3 cannot move beyond 7, and the calling circuit is connected to an idle register.

Sequence switch M23(R4), moving out of position 1, opens its contact D (circuit 20), and relay R20(AMR) de-energises.

24. These are alarm circuits, and L24(RGL) glows to indicate that these are in use.

24*a*. In position 3 the thousands lamp glows, indicating that the thousands impulses are due. It will readily be seen that if a timing device is fitted the state of the registers can be readily ascertained.

Sequence switch M15(R′) in position 5. Circuit 18 is open at 18′ and causes relay R18(S′R′) to de-energise.

25. Dialling tone is given to the calling subscriber, and relay R25(ISR) energises. R25 energises before sequence switch M23(R4) gets to position 3. R4 leaves position 1, and M15(R′) leaves position 4, simultaneously. R4 has two positions, and R′ one position, to advance, so that circuit 25 is established a minute fraction of a second before R4 reaches position 3. This is important because, were it not so, the thousands register would be wrongly set.

26. Relay R26(IGR) energises.

27. Relay R27(ASR) energises.

28. Magnet M28, register R1000 (Fig. 115), energises in parallel with R27, but not the differential relay R29(IDR). R1000, moving out of position 0, shunts the 5·5 winding of IDR by its *a* contact.

29. Relay R29(IDR) energises. Relay R27(ASR) is maintained over circuit 27′.

When R1000 reaches position 1, its *a* contact being open, R27(ASR) de-energises, but

R29(IDR) is maintained energised over circuit 29-27, so that R1000 moves from 0 to 1 before any impulses are sent in.

The Subscriber sends in the Thousands Impulses.—The first interruption, short, opens circuit 25, R25(ISR) (Fig. 115) de-energises and opens circuit 27, R29(IDR) de-energises. Relay R30(L'R) does not have time to energise.

27', 28. R1000 re-energises and moves from position 1 to 2.

29. Relay R27(ASR) switches in circuit 29. The *a* contact of R1000 is now closed until position 2 is reached. IDR and ASR are rendered independent during the time of circuit 27. If the impulses sent in are irregular in character the register is not, within limits, affected.

Again the *a* contact shunts the 5·5 ohm winding of IDR, which energises and opens the circuit at 27". R1000 therefore stops in position 2, when R27(ASR) de-energises. R29(IDR) is maintained over 27*a*, if R25(ISR) is still on its back contact.

The interruption ceases, and R25(ISR) re-energises, and R29(IDR) de-energises. R1000 remains in position 2 until the second interruption takes place, when it and relay R27(ASR) re-energise as before; then R29(IDR) leaves R1000 in position 3, and so on until the eighth interruption. When this ceases relay R25(ISR) re-energises and R1000 is moved into position 9. Relay R27(ASR) de-energises, and R25(ISR) energises. Now comes the final long interruption, and ISR de-energises.

30. Relay R30(L'R) energises.

31. Relay R20(AMR) energises.

23. Magnet M23, sequence switch R4, energises and moves to position 6. Relay R26(IGR) de-energises.

Whilst R4 is moving the long interruption ceases, and circuit 25 is re-established. ISR re-energises. R30(L'R) and R20(AMR) de-energise.

Sequence switch R4 stops in position 6.

26. This circuit is again closed, and relay R26(IGR) energises.

27, 28, 29. These circuits are again established.

32'. Relay R27(ASR) and register R100(M32') energise.

Relay R27(ASR) is maintained over the *a* contact. When R100 reaches position 1, relay R27(ASR) de-energises, and R29(IDR) energises. Thus, R100 is in position 1 and R29(IDR) energised before the hundreds impulses are sent in.

It will be assumed that the number being called is 1,364, and that the first digit has been sent in, as just described, R1000 being in position 9. In dialling the second digit 3, R100 is to be left in position 7. As before described, L'R energises in circuit 30, and on the last hundreds impulse R4 energises in circuit 23 and moves from position 6 to 10.

Sequence switch R4 in passing over position 7 completes—

32. Magnet M32(R5) energises.

33. Relay R33(FGR) energises.

Sequence switch M32(R5) moves from position 1 to 3. Relay R33(FGR) de-energises.

Circuit 26 is opened, and R26(IGR) de-energises, whilst M23(R4) moves from position 6 to 7, thus bringing in a new condition in the alarm circuit. R4 arrives in position 10 before R5 reaches position 3, so that the condition of the switches is as follows:—

M15(R') is in position 5, M19(R3) in position 7, M23(R4) in position 10, M28(R1000) in position 9, M32(R5) in position 3, M32' (R100) in position 7. M57(R10) is in position 1. This is brought about in the manner described for R100.

(If the second digit had been 9, then relay MBR would energise over *f* of R1000 and *e* of R100. This would set up new conditions to choose a special level for operators' lines, etc.)

When sequence switch R5 has passed position 2-

34. Relays R34'(AIR) and R34(UOR) energise.

35. Holding circuit for above.

(If the hundreds digit had been an even one these relays would not have been energised, and R100 would have been in positions 0, 2, 4, 6, or 8.)

When sequence switch R5 passes over position 2

36. Differential relay R36(ODR) energises.

37. Relay R37(AS'R) energises.

38. Register R100 energises.

ODR opens its back contact so that R37(AS'R) de-energises, and R100 advances to position 8, and opens its local contact *d*.

It will thus be seen that in dialling an odd hundreds digit, before the impulses are actually taken out, R100 stands in the same position as it would if the even digit below had been dialled, but relays A'R and UOR remain energised.

When R' arrives in position 3

39. Relays RR10(GLR) and R39(OSR) energise. Circuit 36 then being opened, R36(ODR) de-energises.

40. M15(R1) moves out from position 5 to 6.

INT2 is so arranged that when the trip spindle is in its home position all its contacts are open, but in moving the bottom contact permanently closes, whilst its top contact closes from the time it leaves a position and before it completes one step.

Sequence switch M15(R') in position 6:—

41. Brush chooser M41(P2) energises and in moving closes–

42. By INT2 connecting earth to circuit 39 relay R39(OSR) is short-circuited, and de-energises.

36, 37, 38 are re-established. R37(AS'R) energises.

43. R100 energises and moves from position 8 to 9 and, in so doing, shunts the 5·5 ohm winding of ODR.

44. ODR energises, and is maintained over circuit 43.

When R100 reaches position 9 R37(AS'R) de-energises, it having maintained itself, after ODR energised, over circuit 44 (that is, the *a* contact of R100). If R39(OSR) is still on its back contact R36(ODR) maintains itself over circuit 36, so that R100 cannot make another step until R39(OSR) de-energises. This it does when M41(P2) is making one step, opening circuit 41 and removing the short circuit on R39, thus allowing it to re-energise over circuit 39. R36(ODR) de-energises.

Now brush chooser P2 makes another step and R39(OSR) again de-energises, R100 and R37(AS'R) energise, and, as before, R36(ODR). Before P2 completes its second step the short circuit of OSR is removed, and it re-energises, causing R36(ODR) to de-energise.

R100 arrives at position 0.

45. R1000 energises and moves to position 0.

46. Sequence switch M32(R5) and relay R33(FGR) energise, the former moving from position 3 to 4, and the latter opening circuit 39, thus de-energising RR10(GLR). The brush chooser M41(P2) cannot make any more steps. R5 moving out of position 3, relay R39(OSR) cannot re-energise, and the register cannot make any more steps at present.

47. Contact β of R5 open and R33(FGR) de-energised.

48. Sequence switch M15(R′) energises and moves from position 6 to 7.

49. Relay RR10(GLR) re-energises.

50. First selector brush carriage M50(PG) energises and rotates. The trip spindle or brush chooser makes the brushes of the second level operative, so that PG hunts over the second level for an idle trunk. R12(GTR) tests, as before, but over brush BK. If all the trunks are busy PG will continue to hunt until an idle line is found.

51. R12(GTR) energises, in series with R51(FQR) (Fig. 114) and resistance. R52 in parallel. R51 does not energise.

52. Parallel circuit over R52.

53. Circuit through second winding over GINT, which opens when the brushes of PG are square on the terminals.

54. R14(GT2R) energises, and PG de-energises.

55. SS M15(R′) energises.

56. First selector holding magnet M56(HG) energises in parallel with R′. R′ moves from position 7 to 9, and HG de-energises.

The subscriber having dialled 6 (the third digit), circuit 25 is interrupted as before.

57. Extension of circuit 27 through M57(R10). R10 steps into position 4. R27(ASR) energises in parallel (in a manner similar to that described in connection with R1000 and R100).

Before the units are sent in M23(R4) steps to 13, and M57′(RU) to position 1.

When the units impulses are completed RU is left in 6 and R4 moves to position 16.

57′. Units register RU(M57′) energises, over circuit 27, with ASR in parallel, and R26(IGR) de energises.

Sequence switch R4 passes position 15 and 16.

58. R5 moves from position 4 to 5. R34(VOR) and R34′(AIR) remain energised. R33(FGR) energises while R5 is passing from position 4 to 5. This is done to prevent R59(FLR) energising too soon.

Sequence switch R5 in position 5 :—

59. R39(OSR) and R59(FLR) energise.

60. SS R2 energises and moves from position 1 to 2.

61. Brush chooser M61(P2) of final switch (Fig. 114) energises and makes six steps, in a manner similar to the connecting circuit M41(P2). Register R10 is stepped to 0.

As soon as R10 reaches 0 relay R33(FGR) and R5 energise, and R39(OSR) de-energises, as before, so that when the final brush chooser P2 has made its requsite number of steps it cannot re-energise until it has to be sent to normal at a later period.

Register R10 in position 0.

62. M32(R5) energises and moves from position 5 to 7.

63. R33(FGR) also energises, partly over circuit 62. Circuit 39 is opened, and R39(OSR) de-energises. When the final switch magnet M61(P2) is at rest and INT2 open, R59(FLR) de-energises.

64. R34(UOR) and R34′(AIR) remain energised.

65. M60(R2) energises and moves from position 2 to 5. When M32(R5) left position 5 relay R33(FGR) de-energised and restored circuit 59, so that R39(OSR) and R59(FLR) re-energised.

M32(R5) started to move from position 5 to 7 (two positions) before M60(R2) moved. It

is obvious, therefore, that R5 is in 7 before R2 reaches 5. This ensures that the final brush carriage does not start to move before R5 is ready for it. R59(FLR) is re-energised before R2 reaches 5, so that the latter cannot overstep.

66. Partly over 59. INT1 closes between the steps, and opens when the tripped final brush is fully on the line terminals. It acts in a manner similar to GINT and INT2.

67. When M60(R2) reaches 5 the final brush carriage M67(P1) energises and makes one step, its brushes being tripped by the brush chooser, and in so doing establishes circuit 66 to short-circuit R39(OSR), which then de-energises.

68. R37(AS'R) energises. RU energises and makes one step. R36(ODR) energises as described for INT2. Final magnet M67(P1) completing one step, opens circuit 66. R39(OSR) energises, R36(ODR) and R37(AS'R) de-energise. M67(P1) makes another step, and so on, until it has made six steps, when RU(M57) reaches the normal or 0 position.

If the hundreds digit had been even, R34(UOR) and R34'(AIR) would not have been energised.

69. RU energises and moves out of 0. UOR prevented R5 from moving out of 7, when the units register first came to position 0, because its back contact is open. R33 could not, therefore, re-energise and open circuit 59, to stop M67(P1). In consequence RU has to make ten steps, from 0 to 0, M67(P1) also making ten steps. This brings the brush carriage over to the odd hundreds side of the final switch. If the hundreds digit had been 2 (units 4) RU and P1 would make only six steps, but, the digit being 3 (units 4), RU and P1 each made 16 steps.

When RU left 0, in stepping out the additional 10 impulses it opened circuit 64 at contact *d* of RU, so that R34 and 34' de-energise. When RU reached 0 for the second time INT1 (final) caused R39(OSR) to de-energise.

70. Completed over 68. M32(R5) and R33(FGR) energise. FRG prevents the re-energisation of R39(OSR), and, as M67(P1) has its tripped brushes squarely on the line terminals, NT1 opens circuit 66 and R59 (FLR) energises.

SS M32(R5) moves out of position 7 and, after passing position 8, opens circuit 59, so that R59 cannot re-energise from the register.

Sequence switch M15(R') is now in position 9.

Sequence switch M60(R2) is now in position 5 (ready to move when FLR de-energises).

Sequence switch M32(R5) moving out of position 7 to 8.

Sequence switch M23(R4) on position 16.

Registers R1000, R100, R10 and RU are all in position 0.

65. Relay R59(FLR) de-energises, and M60(R2) energises, and moves from position 5 to 6, R51(FQR) energises.

71. Magnet H(M71) energises.

72. R2 in position 6 causes R59(FLR) to energise.

60. R2(M60) moves out of 6 towards position 10. Magnet M71(H) de energises.

SS R5(M32) has passed position 9, so that circuit 49 is opened, and relay RR10(GLR) de-energises.

73. R'(M15) energises and moves to position 10.

74. R' is again energised and moves to position 11. R' leaving position 9, opens circuit 25, and R25(ISR) de energises.

75. SS R4(M23) energises and moves to position 17. When R4 left position 13, R26(IGR) de-energised, so that when R5 reached position 18 and R14 reached 17—

76. R5 energises and moves to position 1. R33(FGR) also energises, partly over the same circuit, but effects no alteration.

77. R20(AMR) energises and closes circuit 23, so that R4 energises and moves to position 1. AMR de-energises.

The register is freed and made available for another call.

18. Concurrently with the above M15(R′), in passing position 10, causes relay R18(S′R′) to re-energise. R2(M60) is also moving from position 6 to 10. After passing 7, R59(FLR) de-energises, R12(GT′R) and R14(GT2R) also de-energise. R2, in position 8, causes R78(FT′R) to test the line on which the final-switch brushes rest.

Condition 1.—*The called subscriber's line idle.*

78. R78(FT′R) energises.

79. R79(FT2R) energises.

80. SS R2(M60) moves to position 15.

81. Ringing current is sent over the called line.

82. Interrupter W2 causes FLR to re-energise.

60. R2(M60) energises and moves to position 13.

Interrupter W2 opens circuit 82, and R59(FLR) de-energises.

83. Interrupter W3 causes FLR to re-energise, and R2 moves to position 14. W3 opens circuit 83, and FLR de-energises.

84. With R2 in position 14, interrupted ringing current is sent over the called line.

85. R2 in position 12 to 14. Ringing tone is given to the calling subscriber to indicate that the called party is being rung. When R2 is in 12, circuit 61 is completed, and the brush chooser M61(P2) is returned to normal.

84. The called subscriber, answering, increases the current in the line, and relay R81(RGR) energises.

86. R2 energises and moves to position 15, and ringing tone is cut off. The called line is extended to the calling line over 85′.

87. Relay R87(S2R′) energises.

88. M15(R′) energises and moves to position 12. The talking circuit is completed. R′ is in position 12. R2 is in position 15.

If the called party is the first to replace the receiver, circuit 87 is opened, and R87(S2R′) de-energises.

73. M15(R′) energises and moves to position 13. Circuit 51 is opened, and R51 (FQR) de-energises.

89. M60(R2) energises and moves to position 17. R2 is connected to circuit 65 and moves to position 18. When R2 passes position 17, relays FT′R and FT2R de-energise.

90. When R2 reaches position 18 the brush carriage magnet M67(P1) energises and returns to its normal position. In passing the rollers the brushes are relatched.

91. P′ in normal position causes relay FLR to energise.

92. M60(R2) energises and moves to position 1.

93. Magnet M71(H) energises in parallel with M60(R2). R2 in position 1, relay R59(FLR) and holding magnet M71(H) de-energise, so that the final switch is now free.

The calling subscriber clears.

Circuit 18 being opened, R18(S′R′) de-energises, then circuit 87 being opened, R87(S2R′) de-energises.

48. M15(R′) energises and moves to position 17.

94. PG(M50) energises and moves into its normal position, resetting the brushes as it passes the roller.

95. When the brush carriage reaches the home position R14(GT2R) energises. PG(M50) de-energises.

96. R′ energises and moves to position 18.

97. M56(HG) energises. R14(GT2R) and HG now de-energise.

When R′ left position 13 and reached 14, circuit 17 was changed over to circuit 17″ at contact 0. R17′(LCR) de-energises after R′ leaves position 15, so that for two positions of R′ (14 and 15) 96 volts were applied to R17″(SM), causing it to meter the call.

M15(R′) is in position 18 and cannot receive a fresh call in this position. Its companion cord is in position 1, see inset (Fig. 116) on same sheet, and when this takes a call and its R3 moves out over position 1, etc., it completes the following circuit :—

98. R3(R98) energises and moves from position 7 to 10.

99. R3 in position 9½, R87(S2R′) re-energises.

100. M15(R′) re energises and moves to position 1. In this position it may take a call, S2R′ being de energised.

When R′ left position 15, circuit 17″ was opened, so that R17(COR), R17″(SM) and RR17(LH′R) de energised. Thus R′ cannot return to position 1 unless its companion cord has taken a call, and is busy.

Condition 2. *The calling subscriber clears first.*

The operations are as described as far as M15(R′) is concerned, except that, circuit 51 being opened when R2 is in position 15, R51(FQR) de energises and causes R2 to move to 17.

101. R59(FLR) re-energises.

102. Lamp AL glows. Until the called subscriber clears this lamp continues to glow, the final switch testing busy. When the subscriber does clear R59(FLR) de energises, causing the final switch to go to position 1, as before.

Condition 3. *The called subscriber does not reply*

The calling subscriber clears when R′ is in position 11 and R2 in 14, circuit 18 is open, causing R18(S′R′) to de-energise.

103. R103(NMR) energises.

104. Holding circuit for NMR. Circuit 17 is opened, and R17(COR), R17′(LCR), and RR17(LH′R) de-energise, freeing the first line-finder without causing metering.

105. R′ moves to position 17, and R103(NMR) de-energises. PG(M56) moves home over circuit 94. R14(GT2R) then energises over circuit 95, and the connection is cleared, as before described.

Condition 4.—*The called subscriber is busy.*

M15 (R′) is in position 11, and M60(R2) is moving from position 6 to 10, over circuit 60. R2 in 8 tests the line, but R78(FT′R) does not energise over circuit 78 ; consequently when R2 reaches 10 it ceases to move, and busy tone is given to the caller over circuit 106 and 85.

Now when the caller replaces the receiver the clearing is similar to that described for condition 3, except that R2 is in position 10 instead of 14.

R′ passing 12, R51(FQR) de-energises, and R2 moves to position 11, over circuit 89.

90. P1 returns to normal.

91. With R2 in 11 and P1 in home position, FLR energises.

92, 93. H and R2 energise, the latter moving from position 11 to 12. H and FLR de-energise when R2 leaves 11.

With R2 in position 12 P2 returns to normal.

89. R2 continues to move to position 17, and in position 17 switches in circuit 65 and moves to position 18.

In position 18 FLR re-energises over circuit 91. R2 moves from position 18 to 1 over circuit 66, when FLR de-energises and frees the final switch.

Several circuits on the diagram have not been described. These are provided in connection with premature release conditions, dialling special levels, etc., and it is thought can be readily traced.

Section 56

EXPLANATION OF W. E. CO. SYMBOLS USED IN ROTARY SYSTEM DIAGRAMS (Fig. 117), AND NUMBERING OF THE SWITCH-BANKS.

R represents the magnetic clutch of a sequence switch, or the sequence switch itself. The R is sometimes suffixed with a letter or a number to distinguish the different sequence switches used in the same part of a circuit, as for instance, RG, RF, R1, etc.

A represents the "A" contact of the sequence switch and the numbers shown above the lever X are the *stopping* positions in which the "A" contact is open, that is, there is no contact between the lever X and the spring Y.

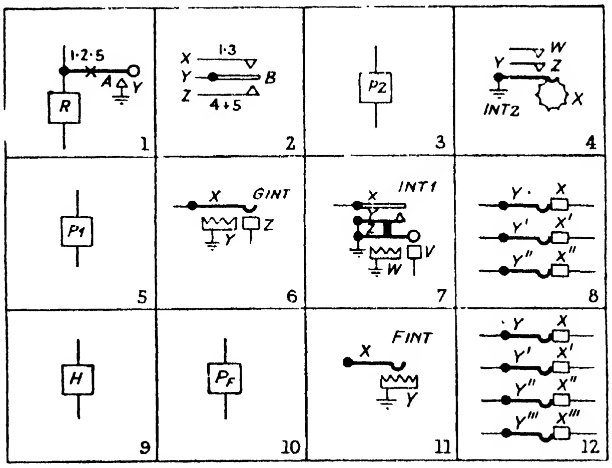


FIG. 117.—APPARATUS SYMBOLS IN W. E. CO.'S ROTARY SYSTEM DIAGRAMS.

A sequence switch has 18 positions at an equal distance of 20 degrees apart.

The normal or "rest" position is 1, and when R starts out from 1, it closes the "A" contact immediately after starting (from 3 degrees to 4 degrees) and remains closed until it approaches the next stopping position, and $2\frac{1}{2}$ degrees to 4 degrees before the actual position is reached, the contact opens; 3 degrees to 4 degrees after starting from position 1, "A" contact closes and remains closed until $2\frac{1}{2}$ degree to 4 degrees before position 2 is reached, then if started out from position 2 R closes again its "A" contact and it remains closed in positions 3 and 4, and opens only just before position 5 is reached, etc.

A register is represented with the same symbol as the sequence switch R suffixed with

a number corresponding to the digit it controls, as for instance, R1000 controls the thousands digit, R100 controls the hundreds digit, etc. The A contact of a register is named with a small letter "a," all other contacts are named with the small letters "b," "c," etc.

B represents one of the 18 sets of contacts (other than "A") of a sequence switch, which are named by the letters from B to S.

The moving spring Y may make contact either with spring X or Z.

The numbers above X show the positions in which there is contact between Y and X and those below Z show the position in which Y makes contact with Z. A contact closes 10 degrees before the actual position and opens 7 degrees after the position, as for instance, if a contact is closed in position 1, it has been closed already 10 degrees before the sequence switch reached position 10, and will remain closed until 7 degrees after position 1 is left. A contact might be closed in more than one position, as shown for the lower "B" contact, which closes 10 degrees before position 4, and remains closed until 7 degrees after position 5, that is, it is closed in 4 and 5 or 4 plus 5. In the drawings, all the contacts belonging to a certain sequence switch, with all the apparatus under its control, are separated with dotted lines.

P2 represents the winding of the magnetic clutch of the trip spindle of a group switch and final selector, or the trip spindle itself.

INT2 represents the trip spindle interrupter. When the trip spindle (P2) is in its *home* position, the contacts Y, Z, W, are open, as soon as the *home* position is left Y and Z make contact and remain closed until P2 returns again to its *home* position. Each time P2 makes a step, W touches Z (which is itself closed upon Y), when Y is on the top of the tooth.

P1 represents the winding of the magnetic clutch of the brush carriage of a group switch and final selector, or the brush carriage itself.

GINT represents the interrupter contact of the brush carriage of a group switch. When the brush carriage (P1) rotates, X makes contact with the top of a tooth of the toothed rack Y, when the brushes are centred upon the corresponding terminals, there is no contact between X and Y. When the brush carriage is in its *home* position, X rests upon the *home* contact Z.

The interrupter contact GINT is sometimes called INT1.

INT1 represents the brush carriage interrupter contact of a final selector.

When the brush carriage rotates, each time Z is on the top of a tooth of the toothed rack W, X and Y make contact, and when the brush carriage is in its *home* position, Z rests upon the home contact V. There is no contact between X and Y, when the brushes are centred upon the terminals.

S represents a set of three brushes, Y, Y′, Y″, of a brush carriage of a group switch or final selector, and a set of three terminals, X, X′, X″, of a terminal arc.

H represents the winding of a holding magnet of any switch. H is sometimes suffixed with a letter, as for instance, HF, etc.

PF represents the winding of the magnetic clutch of a line finder, or the line finder itself.

FINT represents an interrupter contact of a line finder. When the brush carriage rotates, the interrupter X makes contact with the toothed rack Y each time X is upon the top of a tooth, when the brushes are centred upon the corresponding terminals, there is no contact between X and Y.

12 represents a set of four brushes, Y, Y′, Y″, Y‴, of a line finder and a set of four terminals, X, X′, X″, X‴, of an arc.

THE NUMBERING OF THE SWITCH ARCS is as shown in the tables below :—

	Level		1st Gr. Sw.		Arcs of 2nd Gr. Sw.		3rd Gr. Sw.
(Top)	1	..	Recording (0)	..	10,000 to 11,999	..	10,000 to 10,199
	2	..	10,000 to 19,999	..		..	11,000 to 11,199
	3	..	20,000 to 29,999	..	12,000 to 13,999	..	10,200 to 10,399
	4	..	30,000 to 39,999	..		..	11,200 to 11,399
	5	..	40,000 to 49,999	..	14,000 to 15,999	..	10,400 to 10,599
	6	..	50,000 to 59,999	..		..	11,400 to 11,599
	7	..	60,000 to 69,999	..	16,000 to 17,999	..	10,600 to 10,799
	8	..	70,000 to 79,999	..		..	11,600 to 11,799
	9	..	80,000 to 89,999	..	18,000 to 19,999	..	10,800 to 10,999
	10	..	Information 9	..		..	11,800 to 11,999

The arc of the final selectors is numbered as shown in the table below

Level		Final Arc. 1st Half.		2nd Half.
(Top) 1	..	10,000 to 10,009	..	10,100 to 10,109
2	..	10,010 to 10,019	..	10,110 to 10,119
3	..	10,020 to 10,029	..	10,120 to 10,129
4	..	10,030 to 10,039	..	10,130 to 10,139
5	..	10,040 to 10,049	..	10,140 to 10,149
6	..	10,050 to 10,059	..	10,150 to 10,159
7	..	10,060 to 10,069	..	10,160 to 10,169
8	..	10,070 to 10,079	..	10,170 to 10,179
9	..	10,080 to 10,089	..	10,180 to 10,189
10	..	10,090 to 10,099	..	10,190 to 10,199

Hence it is seen that the even hundreds numbers are connected to the first half of the terminal arc and the odd hundreds numbers in the second half, and therefore to choose the units of an odd hundreds number, the brush carriage will have to make 10 more steps than for the same unit number of the even hundred

Functions of the sender of the subscriber's set :—

The dial of the sender is numbered from 0, 1 . . . 9 in a clockwise direction, and when the dial is operated, it produces on its return to normal interruptions of the circuit.

Relation between digits dialled and stepping of machines :—

The table below gives the relation between the digit dialled and the stepping of machines.

0	9	1	0	1	1	1	2	1	11
1	8	1	9	2	1	1	2	2	12
2	7	1	8	3	3	3	4	3	13
3	6	1	7	4	3	3	4	4	14
4	5	1	6	5	5	5	6	5	15
5	4	1	5	6	5	5	6	6	16
6	3	1	4	7	7	7	8	7	17
7	2	1	3	8	7	7	8	8	18
8	1	1	2	9	9	9	10	9	19
9	0	1	1	10	9	9	10	10	20

Section 57

THE WESTERN ELECTRIC CO.'S "ROTARY" AUTOMATIC TELEPHONE SYSTEM FOR 100,000 LINES (Figs. 118–124 inclusive)

The circuits are numbered as follows:—

1. When the receiver is lifted to call the line relay R′ (Fig. 118) energises.
2. The starting relays (CR) R2. R2′ energise.
3. The potential is raised at the test terminal D on the first line-finder arc of the group.
4. All power magnets (PF) M4 of idle first-line finders (Fig. 119) are energised to hunt for the calling line; R4 energises.
5. The line finder whose brushes first reach the calling line extends circuit 3 from terminal D, so that (LTR) R5 energises.
6. R5 holding circuit, through FINT.
7. When the brushes are centred on the terminals, the interrupter FINT opens, and (LT2R)R7 energises. Circuit 4 is opened and magnet M4 de-energises.
8. Holding magnet (H)M8 energises to facilitate the stoppage of the brush carriage in a centred position on the terminals of the calling line. Relays R8, R8′(CR′) energise.
9. A parallel circuit to 8 to raise the potential of the test terminal H.
10. Should it happen that all the first line finders are busy, all circuits 4 will be open, and R4 will not energise, and lamp LGL will glow. This indicates that there are no available line finders.

Should the brushes of two line finders reach the terminals of the calling line simultaneously, and both R5 relays energise, both R7's then energise and lower the potential on terminal D, and the R5's attempt to release. If one R5 releases before the other, the latter will hold with the increased current. If both de-energise, then the line will be taken by any other line finder.

Second Line-finder (Fig. 120).

11. When R8 and R8′ energised they completed a circuit in which R11′(GR) and R11(GLR) energise.
12. Power magnet M12(PF) of the second line finders energises over sequence switch contact H1, and the brush carriages of all idle second line finders rotate.
13. The second finder that first reaches the terminals of the busy first finder extends the circuit 9 from terminal H, and R13(GTR) energises over G1 + 3 of R′(M16) and B9 + 10 of R3(M24).
14. Parallel circuit through FINT to lower potential at terminal H to make it busy to all other hunting second finders.
15. When the brushes of the second finder are centred, FINT opens and R15(GT2R) energises. Circuit 12 is opened and M12 de-energises.
16. Sequence switch M16(R′) energises over C1. M16 starts out from position 1.
17. Holding magnet M17(HF) energises over B1 + 2 in parallel with M16. M17 facilitates the stoppage of the brush carriage with the brushes properly centred on the terminals.
18. M16 immediately closes its local contact to make its energisation independent of the energising circuit 16 which is opened at C1 after position 1.

After position 2, contact S1 + 2 opens circuit 11 and R11 de-energises.

19. M16 in position 3 closes O3 + 13 and R19(COR), R19′(LH′R) and R19″(GSR) energise. The meter SM does not energise. Circuit 1 is opened and the line relay R′ de-energises. Circuit 4 is opened to de-energise all hunting first finders. Circuit 7 is opened and R5 and R7 de-energise. Before R7 de-energised R19′ had already de-energised, so that the power magnet could not re-energise, although the R2 relays are again energised by another line relay of the same group.

Circuit 15 is opened and R13, R15, M8 and R8′ de-energise. Circuit 11 is opened and R11 de-energises (of all the second hunting finders). Circuit 12 is opened and M12 de-energises and all brush carriages cease to rotate.

If no connecting circuits (Fig. 120) are available for the further extension of the connection R11′(GR) will not energise.

20. Lamp GL glows to indicate that no connecting circuits are available.

21. R21(GNR) energises.

22. R22(S′R′) energises over L2 + 4 and J3 + 4.

When sequence switch M16(R′) arrives in position 4 and opens its A contact, it becomes de-energised and ceases to rotate.

Should the brushes of two second finders reach the terminals of the first finder simultaneously, and both R13 relays energise, the potential of terminal H will be lowered so that both relays cannot remain energised after M16 left position 1 and opened its 11 contact. The R13's, and then the R15's will de energise.

22′. When M16 passes position 2, both relays R22′(NMR) energise and prevent the energisation of R19″, when sequence switch M16 reaches position 3, so that the calling line is not made busy until seized by another second finder.

23. Holding circuit of R22′(NMR) over O3 + 13.

The sequence switches of the two connecting circuits return to normal, as will be described later.

Sequence Switch M24(R3) hunting for an Idle Register (Fig. 120).—24. Sequence switch M16(R′) in position 4. M24 energises over sequence contact D4, also I4 of M16, and B9 + 10 of M24, and starts hunting for an idle register.

25. If the register connected in position 1 is free then, when M24 passes position 1 + 2, R25(AMR) and R13(CT′R) energise over B1 + 2 of M16, C1 of M24, P4 + 5 of M16, and B $\frac{1}{2}$ of M24. Circuit 15 is again completed and R15 energises, thus lowering the potential at contact C, and making the register immediately busy to other sequence switches M24. R15 opens the energising circuit of M24, but it continues to rotate over its local contact A.

26. When M24 arrives in position 1 after having opened B $\frac{1}{2}$ and closed B1, M16 energises over B1 of M24 and advances to position 5.

When M16 left position 4 it opened circuit 22, and R22 de energised.

27. When M16 reached position 5, R27(ISR′) energised over the dialling tone coil DTC, monitor's circuit (not shown), O1 of M24, L5 + 9 of M16, through subscriber's instrument, J5 + 9 of M16, L1 of M24.

28. Sequence switch M28(R4) (Fig. 124) energises over P1 and advances into position 3. When M28 closed its local circuit A(29′), it established a circuit in parallel to the holding circuit of R25, and when the sequence switch left position 1, opened the circuit 28 of R25, so that when B1 + 2 opened circuit 25, R25 de-energised. The circuits of R13 and then R15 were opened, and these relays de-energised.

29. When M28 reached position 2, the 10,000's register, M29, energised over 1 2 + 3.

30. Circuit in parallel with 29.

31. Another circuit in parallel with circuits 29 and 30 in which R31(ASR) energises.

32. R31 is quick acting, and completes the previous circuits independently of R27.

33. M29 rotates and closes its local circuit, thus short-circuiting circuit 29 of the differentially connected relay R29, which now energises. M29 arriving in position 1 opens its local circuit and de-energises. The opening of circuit 33 opens circuit 34, and R31 de-energises.

35. When the sequence switch M28 reaches position 2, the dialling tone is transmitted to the caller over N2 ÷ 3, to indicate that the register is ready to receive impulses.

36. The register guard lamp glows over M2 ÷ 11 of M28, and remains glowing until the register is returned to normal.

If two sequence switches M24 simultaneously connect with the same register, and the R13 relays of both connecting circuits become energised, then the potential at the terminal D is lowered so that, when B ½ of M24 opens, the relays R13 and R15 of both connecting circuits remain in the circuit with their low resistance windings only. The relays in parallel do not receive sufficient current, and R13 de-energises and then R15. When M24 reaches position 1 and closes its B1 contact, the circuit of M24 is re-established and the hunting sequence switches continue to rotate as described.

It is assumed that the number to be called is 42,035, and this is reached through the selection of the

Fifth level on the first group switch (Fig. 120).				
Third	,,	,, second	,,	(Fig. 121).
First	,,	,, third	,,	(Fig. 122).
Fourth	,,	,, final	,,	(Fig. 123).
Sixth vertical row on the final switch.				

When the first digit 4 is dialled five short and one long (the last) interruptions of the line circuit are sent.

When the first interruption takes place R27 de-energises, and opens circuit 29, so that R29 de-energises (but R38 has not time to energise); R27 re-energises after the interruption and completes circuits 29, 30 and 31.

37. R31 energising completes the energising circuit for the ten thousands register M29, which starts out from position 1, closes its local circuit 33, short-circuiting the low resistance winding of R29, which energises. M29 reaching position 2 opens circuit 33 and comes to rest. When circuit 33 was opened the holding circuit 34 of R31 opened, so that that relay de-energised.

At the beginning of the second interruption R29 de-energises, if R31 has de-energised as previously described, and the energising circuit of M29 is prepared. After the second interruption R27 re-energises, causing M29 to step into position 3, also as already described. Each time R27 energises the register responds and steps to the next position and, finally, when the fifth interruption is over and R27 energises, M29(R10,000) steps into position 6, and when the last (long) interruption begins, R27 de-energises long enough to energise the slow relay R38(LIR).

38. R38 energises over D3.

39. R25(AMR) energises and completes circuit 28 to energise M28. R25 remains energised, if R27 has already de-energised and opened circuit 38, to de-energise R38. The

energising circuit 39 of R25 is then open and M28(R4) moves from position 3, and advances to 6, under *the control of its local circuit 29′*. R25 remains energised until P3 opens and breaks the circuit 40 of R25.

41. M24(R3) in position 4 M41(R1,000) energises over 14 + 6, with parallel circuits 29, 30, 31 as before described, and advances into position 1. The differential relay R29 remains energised as before. The register is then ready for the thousands impulses.

When the caller dials the digit 2, seven short and one long interruptions are produced. At the first interruption R27 de-energises, then R29 (circuit 29 opened). When the first interruption is finished R27 re energises, and M41 steps into position 2, and will continue to advance each time R27 energises. Finally when the seventh short interruption is over the register will stop in position 8, and when the long interruption takes place, and R38(LIR) energises, and in turn R25, M28(R4) advances to position 8.

42. When position 7 is reached M42(R100) energises over J7+8, and steps into position 1. The parallel circuits 29, 30, 31 are completed as before. R29 energises. The register is then ready for the hundreds impulse.

When the caller dials the hundreds digit 0, nine short and one long interruptions are made, which advance R100 into position 0. When the long interruption begins to take place M28 becomes energised, and advances into position 11, as previously described.

43. In position 9 M43(R10) energises over K9 + 11, and parallel circuits 29, 30, 31 as before. R10 steps into position 1, and R29 energises The register is ready to receive the tens impulses.

When the tens digit 3 is dialled six short and one long interruptions are sent, causing the tens register to step to position 7 and M28(R4) to advance to position 13

44. In position 12 M44(RU) energises over K12 + 13, and circuits 29, 30, 31 are completed. RU advances to position 1, and R29 energises. The register is ready to receive the units impulses.

When the caller dials the units digit 5, four short and one long interruptions are sent, and the RU register advances to position 5, while M28(R4) steps to position 15, where it stops upon the opening of its A contact.

Selection of the Ten Thousands. – After the ten thousands impulses have been sent in and M28(R4), advancing to position 6, arrives in 4:

45. M45(FCR) energises in parallel with 46

46. M46(R5) energises in parallel with 45, over C1 of M46, L4 + 6 of M28, and M46 advances into position 3.

47. R47(ODR) energises over H4 + 16 of M28.

When M46 arrives in position 3, and opens its A contact, its power magnet and R45 de-energise, so that it stops there.

48. R11(GLR) and R48(SIR) energise over N5 + 6 of M16(R′), F1 of M24(R3), Q3 of M46(R5). R47 de energises and prepares the register circuit for the control of the stopping of the trip spindle of the first group switch

49. M16(R′) energises over C5, and advances into position 6, where it stops on the opening of its A contact.

50. The trip-spindle magnet M50(P2) energises over E6 and starts to rotate. It closes the ZY contact of its INT2 interrupter, which will remain closed until the return of the trip spindle into its home position.

51. On the first closure of WZ of INT2 R11 energises over E6, and short-circuits R48, which de-energises.

52. R10,000(M29) energises over $b1 + 9$ and L3 of M46(R5), and in parallel thereto, circuit 47.

53. Another circuit in parallel with 52 and 47. R47 being differentially connected does not energise. R53 energises.

55. New energising circuit of M29, which starts from position 6 and closes its *a* contact (circuit 33), thus short-circuiting the low winding of R47. R47 now energises. When M29 arrives in position 7, and de energises on opening its *a* contact, circuit 53 is opened and R53 de-energises. R47 then de energises, as the first short-circuiting of R48 is over, when it re-energised and opened circuit 47.

When the second short-circuiting of R48 begins, and it de energises, M29 steps into position 8. When the third short-circuiting takes place M29 steps into position 9, and on the fourth short-circuiting it steps into position 0.

56. When the fifth short-circuiting begins to take place and R48 de-energises, M46(R5) energises.

57. R45(FCR) energises in parallel with M46 over D3 of R5, *c*0 of M29, L9 of R5 and in parallel thereto circuit 47, over H4 + 16 of R4. R47 does not energise. R45 opens the fundamental circuit 48. M46 starts from position 3, and advances to position 4 and, closing its A contact, short-circuits the low resistance winding of R47, which energises. When M46 arrived in 4, and opened its A contact, the holding circuit of R45 was opened, and M46 and R45 de energise.

Hunting of the First Group Switch (Fig. 120).—As soon as the fifth closure of INT2 is over R11(GLR) de energises, as circuit 48 is open and opens circuit 50 of M50(P2), which de-energises, and the trip spindle stops after having made five steps.

58. M16(R') energises over Q6 + 7 and advances into position 7.

59. R11 energises over P7 + 9, C1 of M24(R3), G4 + 15 of M28(R4). Circuit 58 is open, and M16 de-energises in position 7 upon the opening of its A contact.

60. Power magnet of brush carriage M60(PG) energises over F7 + 8. The brush carriage rotates and, when passing the trip spindle, the fifth set of brushes are unlatched. The carriage continues to rotate, sweeps over the terminals of the fifth level of the arc, testing for an idle second group switch.

61. When idle terminals are reached, battery is connected over H1 of sequence switch M67.

62. In parallel to 61, R62(GQR) and R13(GTR) energise over terminal and brush K, G7 + 12 of M16, 15 + 7, B1 of R3. Circuit 14 is then closed through GINT, thereby lowering the potential at terminal K, to render the second group switch busy to any other hunting first group switches. When the brushes are centred on the terminals, GINT opens circuit 14, and circuit 15 is extended to energise R15(GT2R).

Circuit 60 is opened and M60 de-energises. M16 re-energises in circuit 16 over C7 + 8.

63. Parallel circuit to 16, in which holding magnet M63(HG) energises, over B7 + 9. HG facilitates the stoppage of the brush carriage with the brushes centred on the terminals. M16 starts from position 7 and advances into position 0 (passing over position 8), where it stops on opening its A contact.

Double Test on the First Group Switch.—Should it happen that the two hunting

first group switches reach the terminals of the same second group switch simultaneously, and their respective R13 relays become energised, then the R15's, and cause the advance of the sequence switch M16 of both connecting circuits from position 7 into 8, the 15 + 7 contact opens after 7, and the R13 relays of both connecting circuits in parallel remain in circuit with their low windings. The potential at terminal K is then so lowered that relays R13 de-energise and, in turn, the R15's. When M16 arrives in position 8, its energising circuit is opened at R15, and both M16's stop in position 8 when the A contacts open. Circuit 60 is again completed, M60 energises, and the brush carriages continue to rotate; no test for a second group switch can be made, as the circuit of the high winding of the R13's is now open at 15 + 7.

64. When the respective brush carriages arrive in their home positions, R15 energises, over H8 and XZ of GINT. Circuit 16 is closed and M16 energises. Circuit 63 is closed, in parallel to 16, and M63 energises. M63 stops the brush carriage in the home position, and M16 stops in position 9. The caller completes the dialling, but no further selection can take place, and no answer being received, the receiver is replaced to release the connection.

Selection of Thousands.—As soon as the thousands digit has been sent in, M28(R4) advanced into position 8.

65. M46 energises over E4 and L7 + 13, and advances into position 6.

66. The fundamental (metallic) circuit. R66(GLR) of the second group switch, (Fig. 121), and R48(SIR) energise, over J1 2, terminal and brush J, X9 of M16, F1 of M24, R6, J6, I1 of M24, K9, brush and terminal I and K1. Circuit 47 is opened and R47 de-energises. The register is now ready for the control of the stepping of the trip spindle of the second group switch.

67. M67(R) energises over B1 and advances to position 2.

68. M68(P2) energises over E2, and the trip spindle starts to rotate, closing the interrupter contact INT2.

69. R48(SIR) is short-circuited at each step, over 12 and WZ contact of INT2. R66 is held energised over circuit 69. M46(R1000) steps from position 8 into 9 and then into 0.

70. Upon the third close of INT2, when R48 de-energises, M46(R5) energises.

71. R45 energises in parallel with 70 over D6, eR of M29, L6, d0 of M41, F6, H4 + 16 of M28. R47(ODR) energises when M28 completes its local circuit. R45 opens the fundamental circuit 66. When the sequence switch M46 arrives in position 7 it stops there, on the opening of its A contact, until the hundreds impulses are sent in.

Hunting of the Second Group Switch (Fig. 121). As soon as the third closure of INT2 is over, R66 de-energises, as the fundamental circuit 66 is already opened. Circuit 68 is open and M68(P2) de-energises and stops, having made three steps.

72. M67(R) energises over C2 and advances into position 3.

73. M73(P1) energises over F3 + 4 and the brush carriage starts to rotate. On passing the trip spindle, the third set of brushes are unlatched and M73 continues to rotate, hunting for an idle third group switch.

74. When an idle line is found a connection is made to battery over O1 + 11.

75. In parallel to 74. R75(GER) and R75′(GTR) energise, over P1, terminal and brush N and G3.

76. Low resistance circuit through XY of GINT.

77. When the brushes are centred on the terminals, GINT opens, and R77(CT2R)

energises. At the same time the potential on terminal N is lowered, and the third group switch made busy to all other hunting second group switches.

Circuit 73 is opened and M73(P') de-energises.

78. M67(R) energises.

79. M79(H) energises in parallel with 78, over B3 + 5, C3 + 4. M79 stops the brush carriage, with the brushes centred on the terminals. M67 advances into position 6, passing over position 4. In 6. R75' is short-circuited, over G6, and de-energises. R77 remains energised.

80. M80 (R of the third group switch) energises over B1 and advances into position 2, where it stops upon the opening of its A contact.

81. Holding circuit of R75, independent of contact P1.

Double Test of the Second Group Switch. Should it happen that two hunting 2nd group switches simultaneously reach the terminals of the same third group switch, and their R75' relays energise and, in turn, the R77 relays, driving out the sequence switch M67 from position 3. When, after 3. contact G3 is opened the low windings of the two R75' relays are in parallel in the connecting circuit, so that the potential at the terminal N is so much lowered that the R75' relays de-energise, then the R77's The SS M67's then arrive in position 4 and open the A contacts, circuit 78 is then opened and they stop in that position. Circuit 73 is completed and M73(P1) energises, and the brush carriage continues to rotate, but no test for a third group switch is possible, as the test circuit is open at G3.

82. When the brush carriage reaches its home position, R77 energises over H4 + 5 and XZ of GINT. Circuit 73 of M73 is opened and M67(R) energises in circuit 78 over C3 + 4. M67 advances to position 5, and no further selection can take place. The connection is then released.

Selection of Hundreds. - After the hundreds impulses have been sent in, SS M24(R4) has advanced from position 8 to 11.

83. M46(R5) energises over B7. O9 + 16, and advances into position 9.

84. The fundamental circuit 66 is again completed and R84(GLR) energises over L1 + 5 of third group switch (Fig. 122), terminal and brush M. circuit 66, brush and terminal L, J1 + 5 of third switch. R48(SIR) also energises and opens circuit 47, and R47 de energises.

85. M80(R) energises over K1 4 and advances to position 5 (passing over position 4).

86. Trip spindle magnet M86(P2) energises over E5, starts to rotate, and closes the YZ contact of INT2.

87. When the first closure of the contact WZ of INT2 takes place, R48 is short circuited over 15. R84 is held over circuit 87. R48 de-energises.

89. R45 and M46 energise in parallel in circuits 70 and 71 to main spring of contact F of M46, thence over circuit 89, until 70, 71 are rejoined. R47, etc. R45 reopens the fundamental circuit 66, and M46 leaves position 9 and passes to 10, and closing its A contact causes the energisation of R47(ODR).

Hunting of the Third Group Switch (Fig. 122). When INT2 opened circuit, *i.e.*, 87, R84 de energised. Circuit 86 is opened and M86(P2) de-energises, having made one step.

89'. M80(R) energises over K5 + 6 and advances to position 6.

90. R84(GLR) energises over I6 and YZ contact of INT2. Circuit 89' is opened and SS M80 stops upon the opening of its A contact.

91. Brush carriage magnet M91(P1) energises in position 6 of M80 over F6, and the

brush carriage rotates. Passing the trip spindle, the first set of brushes is unlatched and the brushes hunt for an idle trunk to the final selector.

92. When the test brush Q makes contact with an idle line, a connection is made to battery over S1 + 4 and R4 of the final switch (Fig. 123).

93. In parallel with 92, R93(FER) energises over R1, terminal and brush Q, and H6 of second group switch. R92(GTR) also energises.

94. Parallel circuit through low winding of R92 over XY contact of GINT. The potential at terminal Q is lowered to make busy the final switch to other hunting third group selectors. When the brushes are centred on the terminals, GINT opens.

95. The circuit is extended through R95(GT2R), which energises. Circuit 91 is opened, and M91(P1) de-energises

96. M80(R) energises over C6 + 8, and leaves position 6 and advances to position 0 on the closure of its A contact, passing over position 8.

97. M97(H) energises in parallel with M80 over D6, C6 + 8, and the brushes are centred on the terminals

After position 6 of M80, R84 de-energises. R92 remains energised in circuit 95. When the M80 arrives in 9 circuit 95 is opened at G6 + 8, and R92 de energises.

98. Holding circuit of R95 over M9 + 11

99. Parallel circuit to R95, in which R93 remains energised.

The testing circuit is prepared and the final switch is ready for the tens digit.

Double Test of the Third Group Switch. If two hunting third group switches arrive simultaneously on the terminals of the same final selector, and their R92's energise, the potential at the terminal Q is so lowered that, when the R95's energise, the sequence switches M80 leave position 6, thus opening circuit 93, when the R95's de-energise. M80 then de-energises when its A contact is opened in position 8 Circuit 91 is completed and M91(P1) energises, and the brush carriage rotates until the home position is reached

100. M97(H) and R95 are energised over D8, home contact XZ of GINT and the brushes are stopped in the home position M80 is energised in circuit 96 over C6 + 8, and advances to position 9. No further selection is possible, and the machines will return to normal.

Selection of the Tens Digit. After the tens impulses have been dialled and the the SS M28(R4) advancing from position 11 into 13 arrives in 12.

101. M46(R5) energises over C10 of R5, M12 + 16 of R4, and advances into position 11.

102. The fundamental circuit 60 - 84 - 102 is completed over L1 + 4 of the final switch, terminal and brush Q, stepping relay R48, J1 + 4 of the final switch, and R102 and R48 energise. R47 de-energises, and the register is ready to control the stepping of the final switch spindle.

103. M103(R) energises over C1, and advances into position 2, where it stops on the opening of its A contact.

104. M104(P2) energises and rotates, closing the YZ contact of INT2.

105. On the first closure of WZ of INT2, R48 is short-circuited over 12 + 4 (R102 is held in circuit 105) R48 de-energises.

106. M43(R10) energises over 61 + 9, M11 and low winding of R47. Circuit 47 is completed in parallel. M43 advances into position 8, as previously described. During the second step of M104, M43 passes to position 9. At the third short-circuiting of R48, M43 returns to position 0.

107. On the fourth short-circuiting M46(R5) energises.

108. R45(FCR) energises in parallel with M46 over B11 + 18, c0 of M43, M11, low winding of R47, then as circuit 106 over H4 + 16, and opens the fundamental circuit 66 + 84 + 102. M46(R5) leaves position 11 and advances to 12, and R47(ODR) energises.

When INT2 opened. R102(FLR) de-energised. Circuit 104 opens and M104(P2) de-energises, after making four steps.

109. M103(R) energises over F2 and advances into position 3, where it remains until the units impulses are sent in.

Selection of Units. After the units impulses have been sent in, M28(R4) leaves position 13 and advances to 15.

110. M28 on reaching position 14 causes M46(R5) to energise over D12, E14 + 15 of M28, and advance to position 14, where the fundamental circuit 66 is completed over J14 of R5. The opening of circuit 106 causes R47 to de-energise. M103(R) energises over C3 and advances into position 4, where it stops upon the opening of its A contact.

111. M111(P1) energises over C4, and the brush carriage rotates, and when passing the trip spindle, the fourth set of brushes are unlatched.

112. When the first short-circuiting of R48 takes place over 12 + 4 and XY of INT1, R48 de-energises.

113. M44(RU) energises over b1 + 9, M14, low winding of R47, then over circuit 106, and steps into position 6 as already described. R48 responding to successive closures of INT1, causes RU to step forward and when the fifth closure of INT1 takes place RU steps into position 0.

114. R45(FCR) energises.

115. M46(R5) energises in parallel with R45 over B11 + 18, c0 of RU, c9 + 0, M14, low winding of R47, then as circuit 106. R45 opens the fundamental circuit 66. M46 leaving position 14, closes its A contact, causing the energisation of R47, and advances to position 16.

Release of the Register (Fig. 124).

116. When M46 passes 14½. R116(VIR) energises over E5 + 15 of M28, K14½ of R5, H2 + 16.

117. Holding circuit of R116.

Circuit 59 is opened and R11(GLR) de energises. Circuit 58 is completed, and M16(R′) energises and advances to position 10.

118. M16 remains energised and advances to position 11 over R10.

When M16 left position 9, circuit 22 is again completed and R22 energises (J5 + 9 and L5 + 9 open and close again in J10 + 13 and L10 + 14).

When M16 left position 9 and opened J5 + 9 and L5 + 9, circuit 27 was opened, and R27(ISR′) de-energised.

119. M28(R4) energises over C15 of M28, and advances into position 16. After position 15, circuit 117 is opened at E5 + 15, and R116 de-energises.

120. M46(R5) energises over D16, c0 of M29, L16, d0 of M41, F16, c0 of M42, N16, G16 of R4, and advances to position 17.

121. R5 is again energised over B11 + 18, c0 of M43, M17, G16, and advances into position 18.

122. R5 is again energised over B11 + 18, *c*0 of M44(RU), *c*9 + 0 of RU, M18, G16 of R4, and advances into position 1.

123. M28(R4) energises over P15 + 16 of R4 and H1 of R5, and advances into position 18.

124. R4 again energises over C18, and advances into position 1, and the register is free for another connection.

Selection of an odd Thousands Number.—If instead of 42,035 the called number had been 43,035 which corresponds on the second group switch to the third level of the terminal arc (as in the case for an even thousands number), and on the third group switch arc to the second level (instead of the first, as in the previous case).

The caller having dialled digit 3, sets the R1,000 register in position 7, and R5 advances from position 4 into 6 (circuit 65).

125. As R5 passes position 5, R125(OTR) (Fig. 124) energises over *c*0 of M41 and G5.

126. Holding circuit of R125 over P5 + 6.

The selection proceeds in the manner described in circuits 67 to 71. After the second short-circuiting of R48, R1,000 steps into position 9.

127. When the third short-circuiting of R48 begins, M46(R5) energises.

128. R45(FCR) energises in parallel with R5 over D6, *c*0 of M29, L6, *f*9 of M41, *c*8 + 9 of M41, F6, low winding of R47, and parallel circuit 47, H4 + 16 of R4. R45 opens the fundamental circuit 66, and R5 advances into position 7. The trip spindle of the second group switch is stopped in a position corresponding to the third level (circuits 72, 77), while M41(R1,000) remains in position 9.

After the hundreds digit 0 has been sent in, setting up M42(R100) in position 0, M46(R5) leaves position 7 and advances to 9. M46 opens its P5 + 6, which opens the holding circuit 125, and R125(OTR) de-energises. In position 9 of M46 the fundamental circuit 66 is established, and when M101(P2) (of the third group switch) produces the first short-circuiting of R48(SIR), the latter then de-energises.

129. M41(R1,000) energises over *c*8 + 9 of M41, F9, *c*0 of R100, N9, low winding of R47, then by circuit 106, and steps into position 0. Sequence switch M46(R5), and relay R45(FCR) energise in circuits 70 and 71 to main spring of contact F, then over circuit 89 to back contact of R47(ODR), then over 70, 71 again, over the following sequence switch contacts D9, *c*0 of M29, L9, *d*0 of M41, F9, *c*0 of M42, N9. R45 opens the fundamental circuit 66, which stops the trip spindle of the third group switch in a position corresponding to the second level. R5 advances into position 10. The further progress of the selection takes place as described for the even thousands digit.

Selection of an odd Hundreds Digit.—Should the called number be 42,035 instead of 42,135 this will correspond to the first level of the third group switch and the fourth level, and the sixteenth vertical row of the final selector arc.

When the hundreds impulses have been sent in, causing the hundreds register to stop in position 9, and when the sequence switch R5 advancing from position 7 into 9, passes position 8.

130. R130(UOR) and R130′(AIR) energise over O8 of R5 and *d*9 of R100.

131. Holding circuit of R130′ over P7 + 12.

132. M42(R100) energises when R5 in position 8½ closes its N8½ and over *d*9 of R100. R100 advances into position 0. The selection then proceeds as for circuits 87 to 90, the trip

spindle of the third group switch stopping in a position corresponding to the first level of the terminal arc.

The selections of the tens proceeds as for circuits 103 to 108, and after the units impulses have been sent in, setting up RU in position 5 and M46(R5), advances into position 14.

133. When leaving position 12 it opens circuit 131 of R130, R130′, at P7 + 12. The relays, however, remain energised over circuit 133, over $d1 + 9$ of RU, H2 + 16 of R5.

When R102 energises, after circuit 110 is completed, and causes the advance of the final sequence switch M103 into position 4 and the establishment of circuit 111, the brush carriage of the final switch starts to rotate.

134. At the first short circuiting of R48(SIR), RU energises over $c9 + 0$ of RU, M14, low winding of R47 (circuit 47). RU steps into position 6 and, responding to the brush carriage stepping, the register continues to step into successive positions up to position 0. When the sixth short circuiting (of longer duration) starts to take place as the brush carriage passes over the long tooth on the toothed rack W of INT1, which separates the two halves of the final terminal arc, RU stepping into position 1, opens its $d0, 1 + 9$ contact. This opens the holding circuit 133 of R130 and R130′, for an interval sufficient to ensure their de-energisation. The stepping circuit at the back of R130 is re established and, when the seventh short circuiting of R48 starts to take place, the further stepping of RU occurs as previously described. The brush carriage is allowed to make 10 additional steps, which return the RU to position 0, and the brushes stop upon the terminals of the third level and the sixteenth vertical row. The release of the register takes place as previously described.

Release of Register after Selection of an odd Hundreds and Zero Units Number.—If the called line should be 42,130, which corresponds to the first row on the second half of the terminal arc, then when the caller dials the hundreds R100 will be set in position 9, circuit 130 will be closed and R130 and R130′ will energise. After the units have been dialled, setting RU in position 0, sequence switch R5 advances to position 14.

135. R135(MBR) energises, when R5 passes position 13 over $f + 0$ of RU, O13, $d0$ of RU and H2 + 16.

136. Holding circuit of R135 over H2 + 16. After the units selection is over and R5 advances from position 14 to 16, as above, K14½ of R5 is opened (circuit 116) and R116(VIR) will not energise until R5 has closed its K15 + 16.

137. R116(VIR) energises over E5 + 15 of R4, K5 + 15 of R5, H2 + 16. M16(R′) energises in circuit 58 and advances to position 10. By this arrangement the change over of the connecting circuit from the register to the talking circuit is delayed by a time sufficient to ensure that the contact L1 + 4 of the final switch opened before the contacts M10 + 15 and K10 + 15 of M16 closed.

Testing of the Called Line (Fig. 123).—After the closure of INT1 is over, R102(FLR) de-energises, as the fundamental circuit has already been opened (following circuit 115).

Circuit 111 is opened after the brush carriage has made six steps and M111(P′) de-energises.

138. Circuit 109 is completed over F4, and circuit 138 is completed in parallel over B4 + 6, and M103(R) and M138(H) energise. M138 stops the brush carriage with the brushes centred, and M103 closes its A contact and advances to position 6. L1 + 4 of the final switch opens before K10 + 12 and M10 + 12 of M16(R′)

139. R102 energises, when M103 is in position 5, over G5 + 6. When M103 arrives in position 6, its energising circuit 103 is already re-established over C6 and advances into position 10.

140. When M103 passes position 7, and the called line is idle, R140(FTR) energises over the COR and service meter SM in parallel, terminal and brush C″ and G7.

141. Parallel circuit through the low winding, in which R141(FT2R) energises. The potential at the C″ terminal is lowered to make the line test busy

142. When M103 arrives in position 10, it continues to advance to position 12 over E6 + 11. It passes over position 11.

143. Holding circuit of R140, R141 and COR, when M103 is in position 12, over G12 + 17, H12 + 17.

144. Ringing current to called line over pole of ringer, P12 13 brush and terminal B, instrument, terminal and brush A, K12 14. R144(RGR) does not energise.

145. When the interrupter W3 closed, R102(FLR) energised over O12. M103 energises in circuit 103, over C11 14, and advanced into position 13. When leaving position 12, R102 de-energises.

146. In position 13, when W2 closed, R102 energises again over N13. M103 re-energises in circuit 103 and advances into position 14.

147. Interrupted ringing current is sent to line over M14.

148. Tone circuit during the period M103 is in positions 12 14, over Q12 + 14.

149. Secondary circuit to calling line, to tell that called party is being rung.

150. When M103 reaches position 12 M104(P2) energises over D12 1, ZY contact of INT2, and rotates until the home position is reached where INT2 opens, and M104 de-energising stops in its position of rest

, After position 4 circuit 92 is opened at S1 4 R95 remains in circuit with the high resistance of R93, and R95 de energises while R93 remains energised.

151. M80 (R of the third switch) energises over F9 11, and advances to position 12 (passing over 11), and stops upon the opening of its A contact.

152. M86(P2) energises over E12 1, YZ contact of INT2, and the trip spindle rotates until the home position is reached where the INT2 opens and M86 de-energises and stops the spindle in the position of rest

M80 leaving position 11 opens its H 11, and R77, being in series with the high resistance of R75 de energises while R75 remains energised. After position 11, circuit 95 was opened at G9 11 and R95 de-energised, while R93 remains energised in circuit 99.

Double Test of the Final Selector. Should it happen that the brushes of two final selectors test the same subscriber's line simultaneously, their R140 relays become energised and in turn the R141's. After G7 opened, leaving the low winding of R140 in circuit only, the potential at the terminal C″ is so low that the R140's de-energise, then the R141's. When the sequence switches M103 arrive in position 10, their energising circuits 109 are opened, and M103 stops in the busy position and the busy tone is transmitted to the caller.

The Called Party answers. When the receiver is lifted to answer R144 energises.

153. M103 energises over C11 14 and advances into position 15.

154. The talking circuit, in which R154(STR) energises over M10 + 12 of the first switch, brush and terminal J, J6 of the second switch, brush and terminal M, L9 + 12 of the third switch, brush and terminal P, M15 of the final, brush and terminal B′, instrument,

terminal and brush A′, K15 + 17, terminal and brush O, J9 + 12, terminal and brush L, K6, terminal and brush I, K10 + 12.

155. M16(R′) energises over C11 and advances into position 12.

Release of the Connection.—When the calling receiver is replaced, circuit 22 is opened and R22 de-energises. Circuit 58 is completed and M56 advances into position 17, passing over position 13. After position 12, G7 + 12 opened and R13 and R15 de-energised.

156. The service meter M156(SM) energises and registers in position 14 of M16, O14 + 16, brush and terminal G, brush and terminal C. During the change over of O3 + 13 to O14 + 16, the circuit is opened for a short period, but R19′, being slow to release, remains energised. J10 + 13 opens before O3 + 13 after position 13. After position 16 O14 + 16 opened, and opened circuit 156, and R19 M156, R19′ and R19″ de energised. The subscriber's line is now in the calling condition. The line finder is now free. R21 de-energises.

157. In position 17 of M16, M60(PG) energises over F17, H17, B1 of M24, and the brushes are rotated. When they pass the restoring roller the set of tripped brushes are latched and returned to the home position.

158. R15(GT2R) energises over H16 + 17 and XZ of GINT. Circuit 157 is opened and M60 de energises.

160. M16 energises and advances into position 18, where it waits until the second connecting circuit of the sub-group takes up a call. M63(HG) energises in parallel with M16, over B17 + 18, C16 + 18, H17, B1 of M24, and the brushes are stopped in the home position.

161. M50(P2) energises when M16 is in position 18 over E18 + 5, and YZ of INT2. The trip spindle rotates until the home position is reached, when YZ opens and opens circuit 161, to de-energise M50, which stops in the home position.

Normal Positions of Connection Circuits. To reduce the number of hunting second line finders, when a call is made the connecting circuits are arranged in sub-groups of two, in such a way that when both are free, only one of the connecting circuits has its sequence switch M16(R′) in position 1, while the other remains in 18 waiting for the first to be engaged. If we assume that the second connecting circuit of the sub-group has taken a call, its M16 arriving in position 4 completes the circuits of its M24(R3), which starts to rotate, to hunt for an idle register.

162. As soon as this searching sequence switch leaves its normal position 10, and arrives in 1, it closes its S1 + 9, when M24 of the connecting circuit (with M16 in 18) energises over D18 and S1 + 9 of the hunting M24, which rotates.

163. M24 when passing 9½, R154(S2R′) energises over M15 + 18 of M16, R9½ of M24.

164. M16 energises over C16 + 18, and advances into position 1. The other M24 arriving in 10, finds its energising circuit open at D18 de-energises and stops in its rest position 10. It is then ready for another call.

165. When M16 left position 12, R62 de-energised. M67 (R of second switch) energised over D6 and advances into position 10. Circuit 73 is then completed and M73(P′) energises over F10 and rotates. The brushes are latched and continue to rotate until the home position is reached.

166. R77 energises over H9 + 11 and XZ of GINT. Circuit 73 is opened and M73 de-energises.

167. M67 energises and advances into position 1.

168. M79(H) energises over B10 + 11 and then in parallel with M67 over C10, and facilitates the stoppage of M67.

169. In position 8 of M67, M68(P2) energises over E8 + 1 and YZ of INT2, and rotates until the home position is reached. INT2 is then opened, M68 de-energises and the trip spindle remains in its normal position. The second group switch is now ready for another call.

170. When M67 (Fig. 122) left position 6, circuit 81 was opened and R75 de-energised. M80 then energises over B9 + 12 and advances into position 14. Circuit 91 is completed and M91 energises over F14 and rotates. When passing the restoring roller, the brushes are latched and the brush carriage rotates to the home position. Circuit 100 is completed and R95 energises. Circuit 91 is then opened and M91 de-energises. Circuit 96 is completed. M80 energises over C14 and advances to position 1. The third group switch is now ready for another call.

171. Circuit 99 is opened and R93 de-energises. M103 (R of the final switch) then energises over B12 + 17 and advances into position 17. If the called receiver has been replaced, circuit 171 is still completed at B12 + 17, and M103 advances into 18. After position 17, H12 + 17 and G12 + 17 are opened (circuit 140), and COR, R140 and R141 de-energise, thus freeing the called line.

172. M111 energises with M103 in position 18 over F18, and rotates, latching the brushes on the way to the home position.

173. R102 energises over O18 and ZV of INT1. Circuit 172 is opened and M111 de-energises. Circuit 103 is completed and M103 and M138 energise in parallel over B18, C18. The brush carriage is stopped in its home position and the sequence switch advances to position 1. The final switch is ready for a new call.

Called Subscriber's Line busy.—When sequence switch M103, advancing from position 4 into 10, passes over position 7, then testing the called line circuits 140, 141, and finds the line busy, the potential at the terminal C′ is too low for R140 to energise and close circuit 141. When M103 arrives in position 10 and opens its A contact, it de-energises because circuit 142 is open and stops in position 10.

174. A busy tone is induced in the secondary of the induction coil by the primary over Q10 and the interrupter, and is heard by the caller. M16 remains in position 11.

The caller replaces the receiver, circuit 22 is opened, and R22 de-energises.

175. R22′ energises over Q11. Circuit 19 is opened and the calling line and the first finder are released. Holding circuit 23 of R22′ is completed over O13.

176. M16 energises over I9 + 14, B1 of M24, and advances to position 17. The machines return to normal and metering is prevented.

When R93 and R75 de-energised, circuit 171 is completed, and M103 energises over B10 and advances into position 11. Circuit 172 is then completed and M111 energises over F11, and rotates until the home position is reached. Circuit 173 is completed and R102 energises over O6 + 11 and ZV of INT1. Circuit 172 is opened and M111 de-energises. Circuit 103 is completed and M103 and M138 energise in parallel over B11, C11 + 14. M138 stops the brushes in the home position, and M103 advances into position 12, opening, after 11 circuit 173, so that R102 de-energises. In position 12 the energising circuit of M103 is closed over F12 + 17 and advances into position 18, and, finally, returns to normal, as already described.

Selecting a Private Branch Exchange Line (Fig. 123).—The P.B.X. final switches are equipped with the part of the circuit shown in dotted lines, and the full line marked with

an X from R102 to G5 + 6 (circuit 139) is omitted. If the called subscriber belongs to a P.B.X. group, then, when the brush carriage stopped upon the first line of the group, M103 advancing from position 4, reaches position 5.

177. If the first line is idle, R177(PBR) energises over G5 + 6.

178. R141 energises, and circuit 172 is open, when M108 arrives in position 6. Circuit 142 is completed and M103 energises over E6 + 11, has its energising circuit closed, and advances into position 10. Leaving position 6, circuit 177 is opened at G5 + 6 and

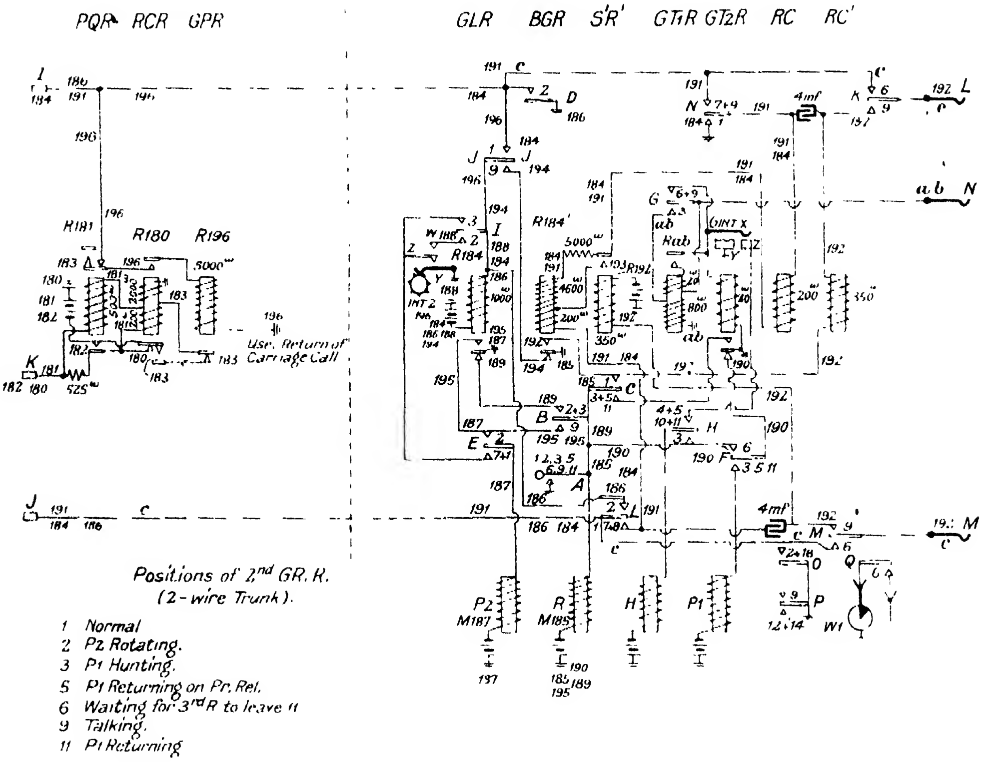


Fig. 125.—W. E. Co.'s Rotary System. Second Glroup Sector for Two-rwie Trunks.

R177 de-energises. While passing position 7, the ordinary test circuit is re-established at G7, the line made busy, and the final switch advances to the ringing position, as already described.

When M103, advancing to position 6, arrives in 5 and closes its G5 + 6, if the first P.B.X. line is busy, R177 will not energise. When M103 arrives in 6, its energising circuit is opened, but M111 energises in circuit 172 and rotates until the next idle line of the group is found. R177 then energises. R141 is short-circuited over 16 and XY of INT1, and does not energise until the brushes are centred and INT1 opened. M111 de-energises. Circuit 142 is completed and M103 and M138 energise, in parallel, over B4 + 6. M138

stops the brushes and M103 advances to 10, so testing and making the line busy as before.

If all lines of the group are busy the brush carriage of the final switch will rotate until the last line is reached, and there R177 will energise, whether the line is busy or idle, as the COR is shunted by a 430-ohm non-inductive resistance (not shown). This causes the advance of M103 into position 10, and, while passing 7, the test circuit will be established over G7. The line being busy, R140 will not energise, and M103 will stop in the busy position 10. Busy tone will then be transmitted to the caller.

Connection with a Distant Office (Fig. 125).—Two-wire trunks are used between offices. These are connected for outgoing service from one office on a predetermined level of the first group switches. At the other office they connect with brushes of second group selectors, the other switches being as before described When a connection is required in the second office, the first digit dialled causes the test brush of the first switch to connect with an idle two wire trunk.

180. Battery is connected over terminal and brush K.

181. R180(RCR) and R181(PQR) energise over terminal and brush K, G7 + 12, through R13, as in circuit 62, etc.

182. Parallel circuit to terminal K.

183. R180 holding circuit.

When the thousands impulses are sent in, M46(R5) advances into position 6, and establishes the fundamental circuit.

184. R184(GLR) and R48(SIR) do not energise over the fundamental circuit 66 + 84, over terminal J, L1 and N1, being in series with high winding of R184′(BGR), which energises.

185. Sequence switch M185(R) energises over C1 and advances into position 2. After position 1, circuit 184 is opened and R184 de-energises.

186. R184 and R48 now energise over L2, brush J, fundamental circuit, terminal J and D2.

187. M187(P2) energises and the trip spindle rotates. The further selection of the thousands takes place as before described.

188. When selection is completed, and the fundamental circuit opened at the back of R45(FCR), R184(GLR) de-energises after the contact WZ of INT2 is opened. Circuit 187 is then opened.

189. SS M185(R) energises over R2 + 3 and advances into position 3. R184 energises in circuit 188 over 13 and YZ of INT2. SS M185, in position 3, opens its A contact and comes to rest.

The hunting of the brush carriage and the advance of the sequences switch into position 6 takes place as in circuit 78. After selection is over, the final switch, leaving position 4, causes the SS of the third group switch to leave position 11, and R77 (GT2R of second switch) de-energises (see circuit 152 and following).

190. SS M185 energises over F6 and advances to position 9, and closes its M9 and K9 contacts.

191. In position 7 of M185, R154 is in series with R184 and does not energise, R184′, however, energises over M10 + 12 of first switch, terminal J, L7 + 9 of second group switch, N7 + 9, brush I, K10 + 12. M16 is thus kept in position 11 until the called party answers, as already described.

192. When the subscriber answers, R192(S'R') energises over M9 of second switch over subscriber's line and K9 of the second switch.

193. Short circuit of high winding and resistance of R184. R151 is, however, in circuit 191, and energises. Circuit 155 is completed, and SS M16 advances into position 12, as before.

When the caller replaces the receiver R22 de-energises." Circuit 191 is opened, and R184' de-energises.

194. R184 energises over J9.

195. SS M185 energises over B9 and advances into position 11, and returns to normal, as before described.

When SS M16 leaves position 12 and opens contact G, R181 de-energises. R180 remains energised in circuit 183.

196. Circuit to keep trunk busy. When M185 arrives in position 1, circuit 196 is extended through the A wire and J1, and R196(GPR) energises. Circuit 183 is opened, R180 de-energises and re-establishes the test circuit, and the second switch is ready for another call. The other switches are released as before.

Breaking down a Local Connection for a Trunk Call.—If a line is engaged in a local connection, but is required for a trunk call, the local call is broken down by the trunk or toll operator applying a direct earth at the test terminal C. If the line wanted has been called for on the local connection, R140 and R141 are short-circuited, and will de-energise. Circuit 109 is thus completed, and M103 energises over F12 + 17, and advances into position 18. Circuit 172 is then completed, and M111 energises over E18 and returns to its home position and stops there. M103 finally returns to position 1, as described after circuit 173. The trunk of the final switch is kept busy by the low potential at the terminal Q over circuit 99. When the caller replaces the receiver, the release of the connection will take place as previously described. When R75 of the third group switch is de-energised, R93 will de-energise and the final switch is free for another connection.

Should it happen that the calling party on a local connection is wanted, then, when earth is applied to the test terminal C, R19' and R19" are short-circuited and de-energise. Circuit 21 is opened and R21 de-energises.

197. R22' (Fig. 120) energises over J10 + 13. Circuit 19 is opened and R19, R19' and R19" are cut off. Holding circuit 23 of R22' is completed over O3 + 13. Circuit 176 is completed, and M16 energises over 19 + 14 and B1 of M24 and advances to position 17, passing over 13. Circuit 156 is open, and the booster battery is disconnected, and the meter does not register. The return of the machines to normal is as before described.

Section 58

THE WESTERN ELECTRIC CO.'S "CARRIAGE CALL" (Fig. 126)

This is a very valuable adjunct on a system of mixed manual and automatic offices for indicating, at the B manual positions, the called number dialled by a calling subscriber on an automatic office. The impulses are received on registers at the automatic office and given out by these to registers and sequence switches at the manual office, which cause one of a set

of 10 lamps associated with each register switch there to glow. The B operator thus reads the number wanted from the glowing lamp in each strip of 10, there being as many strips as there are digits in the number. The trunks end in single cords or on keys, and there is a calling lamp associated with each plug or key to identify the trunk. These are sometimes associated with B operator's positions placed between manual offices and an automatic office.

To the left of Fig. 126 the terminals of the first group switch in the automatic office are indicated by L, J, K. The vertical dotted line indicates the trunk line interval between the manual and the automatic office. Four figure numbers are assumed for the manual office.

The trunks incoming to an operator's position have access to two registers, which control a common call indicator equipped with the corresponding number of lamps. While both registers of an operator's position are being set, the outgoing ends of the remaining free trunks of that position are insulated by opening the outgoing end of the test wires. This is under the control of two sequence switches ROT and ROT'. The same sequence switches insulate the trunks of an operator's position when it is vacant.

Other features will be pointed out when describing the diagram.

The circuits are numbered as follows: --

When the first digit is called and the sequence switch of the first group switch moves to position 7 (Fig. 120), the brush carriage PG starts to hunt for a free trunk to the carriage call position.

1. Relay R'(UHR) energises over wiper K and the following in the automatic office (Fig. 124), through GT'R, back of NMR to earth (circuit 13), when GT'R and UHR(R') energise. The trunk is made busy and the sequence switch (at auto.) advances to position 9, as for an automatic connection.

2. Holding circuit of R'(UHR).

3. R3(BG'R) energises. R5(Q3R) does not receive sufficient current to energise.

4. R4(VQR) energises. Short-circuit removed from R4'(LH3R), and the latter is slowly energised in series with R4.

5. The high resistance of R3 is short-circuited and R5(Q3R) energises.

6. R5 7,000-ohm winding is in parallel with the 400-ohm winding.

7. Lamp GL glows and relays R7(DRR) and R7'(PLR) energise.

8. Pilot lamp glows, indicating trunk busy.

9. Power magnet M9(P) of the brush carriage of the line-finders of both registers is energised. The corresponding brush carriages rotate and hunt for the calling trunk.

10. The first that makes contact with the terminals completes this circuit. R10(GT'R) energises.

11. Low resistance circuit through FINT to earth to make trunk busy to the other hunting line-finder.

12. When the brushes are centred on the terminals, FINT opens and GT2R(R12) energises. Circuit 9 is opened and M9(P) de-energises.

13. Circuit for sequence switch M13(R'L).

14. Parallel circuit to M13 in which the holding magnet M14(H) of the line-finder is energised. It controls the stopping of the brush carriage. M13(R'L) advances from position 1 to 4.

15. When approaching position 3 R10(GT'R) re-energises. Circuit 11 and 12 is completed, and relays R15(VPR), R15'(VP'R), R12(GT2R) energise.

16. R16(VOR) energises.

17. R16 high winding in parallel with low to make it independent of VP'R(R15'). R16 opened circuit 7 and R7(DRR) de-energised. Circuit 9 is opened and the magnet M9(P) of the other still hunting call-finder is de-energised.

Setting up the Registers for a Carriage Call.—Suppose the called number to be 2,455. The corresponding registers will be set in the positions 8, 6, 5, 5.

18. The fundamental circuit 66 (Fig. 124) is established from the automatic office. When R15(VPR) energises, the fundamental circuit is from battery, R2 plus 11, GLR, back of NMR, brush and terminal L, front of VPR, terminal and brush J, through the fundamental circuit (as described for Fig. 116), brush and terminal I, A wire of trunk, front of VPR to earth.

When the thousands impulses have been sent in and R5(M46) (Fig. 124) advances to position 6, closing the fundamental circuit 66, GLR energises in series with S'R.

19. M13(R'L) energises and advances to position 5.

20. R1,000(M20) is energised and advances to position 2.

21. While passing position 1 -- $1\frac{1}{2}$, this circuit is established to short-circuit the stepping relay S'R, which, de-energising, causes the register of R1,000 to advance into position 9.

When B1 $\frac{1}{2}$ opened and removed the short circuit of S'R, the latter energised and prepared the register for the reception of the second impulse. The lamp register M20, R1,000, continues to advance from position 2 to 3, and passing position 2 – $\frac{1}{2}$, closes its B contact, again short-circuiting S'R, which, de-energising, establishes a circuit for R5 and FCR in parallel (Fig. 124). The latter, energising, opens the fundamental circuit while R5 advances to position 7, where it waits for the hundreds impulses to be sent in.

When circuit 21 opened, R18(GLR) de-energised and opened circuit 20, so that R1,000 stopped in position 4 after having opened its A contact.

22. R13(R'L) is again energised and advances to position 6, where the sequence switch waits for the closure of the fundamental circuit, which will take place after the hundreds impulses have been sent in and R5 advanced to position 9.

When the hundreds impulses have been sent in, GLR and S'R energise. Circuit 19 is completed through 16 and M13(R'L) advances to position 7.

23. M23(R100) energises and advances to position 2.

24. While passing B1 - $\frac{1}{2}$, S'R is short-circuited and de-energises and causes the advance of the register R100 to position 7. When the lamp register M23(R100) steps into position 3, the register R100 is caused to step into position 8. When M23(R100) steps into position 4 the register steps into position 9. When M23(R100) steps into position 5 the register R100 steps into position 0, and when M23(R100) steps into position 6, R5 and FCR (Fig. 124) become energised. The former opens the fundamental circuit and the latter advances into its waiting position 10.

When circuit 24 opens, R18(GLR) de-energises, opens circuit 23 of R100, which stops in position 6 after having opened its A contact. Circuit 22 is again completed in position F7, causing M13(R'L) to advance to position 8, where it waits for the fundamental circuit to be closed.

When the tens impulses have been sent in and R5 (Fig. 124) has advanced into position 11, closing the fundamental circuit, R18(GLR) and S'R energise. The former completes circuit 18 when the sequence switch advances to position 9.

25. The lamp register M25(R10) energises and advances to position 2.

26. S'R (Fig. 124) is short-circuited in the manner already described, and causes the

R10 register to advance into position 6. When M25(R10) steps into position 3, R10 (Fig. 124) register is caused to step into position 7, etc. When M25(R10) steps into position 6, the R10 register is caused to step into position 0, and when M25(R10) steps into position 7, FCR and R5 (Fig. 124) become energised. The former opens the fundamental circuit while the latter advances to its waiting position 12.

As soon as the circuit 25 is opened, R18(GLR) de-energises and opens circuit 25 of R10, which stops in position 7 after having opened its A contact. Circuit 22 is again completed over F9, and M13(R'L) energises and advances into position 10, where it waits until the fundamental circuit is closed.

When the unit impulses have been sent in, and the sequence switch R5 (Fig. 124) advanced into position 14, closing the fundamental circuit, R18(GLR) and S'R energise. Circuit 19 is completed over 110, and M13(R'L) energises and advances to position 11.

27. M27(RU) energises and advances to position 2.

28. S'R is short-circuited, as before, and the RU register is caused to step into position 6. When M27(RU) advances into position 3, the register RU (Fig. 124) is caused to step into position 7, etc. When M27(RU) advances into position 6, the register RU returns to position 0, and when M27(RU) advances into position 7, FCR and R5 energise. The former opens the fundamental circuit and the latter advances into position 16, and the release of the register takes place.

When circuit 28 was opened, R18(GLR) de-energised. The switch M27(RU) stops in position 7 after having opened its A contact.

Circuit 22 is completed over F11 and M13(R'L) advances into position 14.

Lighting of the Indicator Lamps. The two register circuits are so inter-connected that when the lamps glow a call, arriving through another register, will not advance until the operator has attended to the first call; that is, if sequence switch R2L (of the second register) is not in position 16 when the lamps glow.

If no other call is waiting, and R2L is not in position 16

29, 29'. Alternative circuits in which M13(R'L) energises and advances into position 16.

30. No. 2 lamp of L1,000 glows.

31. No. 4 lamp of the hundreds glows

32. No. 5 lamp of the tens glows

33. No. 5 lamp of the units glows.

The four glowing lamps indicate the number 2,455.

When the sequence switch R'L left position 14 it opened circuit 15, and relays R15(VPR), R15'(VP'R) de-energised.

34. Holding circuit of R10(GTR). FTR at automatic office and R12(GT2R) remain energised in circuit 12 and 18. R15'(VP'R) opened circuit 16, but R16(VOR) is held in circuit 17. Lamp GL ceases to glow

35. The calling lamp CL glows.

36. The talking circuit is established, and M16(R') at the automatic office is stopped in position 11.

Setting up an odd Thousands Number. If the called number had been 3,455 instead of 2,455 the automatic registers would have been set in positions 7, 6, 5, 5, and the lamp indicator registers would set up the R1,000 switch one step short, as the R1,000 register will remain in position 9. But an additional step will be added on the R100 switch, which

will stop in position 7. M13(R'L) will then advance to position 16 of the thousands indicator lamps.

37. No. 3 lamp of L1,000 glows. The other lamps glow as already described.

Setting up an odd Hundreds Number.—Should the called number have an odd hundred, the RU switch will make an additional rotation.

38. When passing position 11 – ½, R38(DKR) energises.

39. R38(DKR) holding circuit.

40. The corresponding lamp in the L100 group glows.

Release of the Register and Ringing the Called Party.—The operator, seeing the required number displayed, tests the line wanted with the plug corresponding with the glowing CL lamp, and if the line is idle inserts the plug into the jack.

41. R41(KDR) and R41'(ENR) energise. R41' opens the circuits 7, 15, 16, etc., and R16(VOR), R7'(PLR), R10(GT'R) and R12(GT2R) de-energise, and lamp CL ceases to glow. R7' opens circuit 3 and lamp PL ceases to glow.

42. R42(NMR) energises.

43. R42 holding circuit in which M13(L'R) energises and advances to position 17. When leaving position 16 the indicator lamps cease to glow.

44. R1,000 energises and returns to its normal position 1.

45. R100 energises and returns to normal position 1.

46. R10 returns to normal position 1.

47. RU returns to normal position 1.

48. All the registers being in position 1, M13(R'L) energises and returns to position 1. On leaving position 17, circuit 42 is opened and R42(NMR) and R22(GT2R) de-energise. The registers are ready for a new call.

49. R41(DKR) completed a circuit for the S2R1 of the connecting circuit, causing S2R to energise, which in turn caused M16(R1) to advance to the talking position 12. Meantime the operator has rung the called party, and, when the subscriber answers, conversation takes place.

Releasing a Connection.—When the calling party replaces the receiver the automatic machines return to normal, as described for Figs. 118–124, and the message register (meter) operates.

When circuit 1 of R'(CHR) is opened at the terminal K relay, R' de-energises. Circuit 5 is opened, but R5(Q3R) remains energised in circuit 6. R3(BG'R) de-energises, but R5 remains energised to keep the trunk busy.

50. Lamp S'L glows until the called party clears.

51. When the called party clears, R51(MSR) operates and lamp S2L glows, and the operator withdraws the plug. R41 and R41' de-energise. R41' opens circuit 50, and lamp S'L ceases to glow. R41' also opens the circuit of R4 and R4'. The former, de-energising, opens circuit 5, and R5(Q3R) de-energises. The operator momentarily operates the speaking key to open circuit 51, and MSR(R51) de-energises and lamp S2L ceases to glow. The trunk is returned to normal.

Called Party Busy.—When the called line tests busy, the trunk plug is inserted into the busy jack.

52. This circuit is completed over circuit 41, and R41' energises. Owing to the resistance

of 2,400 ohms, R41 does not energise, and M16(R1) of the connecting circuit is kept in position 11.

53. Busy tone is given to the calling subscriber.

The remaining operations are as before described, and when the caller replaces the receiver the connection is released without metering.

Premature Releases.—The calling receiver may be replaced just before the register is connected and cause a premature release. R3(BG'R) de-energises and, in turn, R7 and R7' de-energise. Lamps GL and CL cease to glow, and the circuit is returned to normal.

A premature release may occur when both registers get connected simultaneously to the same trunk. Then when M13(R'L) leaves position 1 and opens the circuit of the high resistance winding of GT'R, that relay and GT2R de energise.

54. When M13 passes position 2, R42(NMR) energises and opens circuit 10.

55. M13(R'L) energises and advances to position 17.

56. R18(GLR) energises and opens the test circuit, when R15 passes position 3. The circuit is finally returned to normal in known manner.

Functions of the Timing Sequence Switches ROT and ROT'.

57. When a position is occupied and the instrument plug is inserted in the jack, R57(GPR) energises.

58. The sequence switches M58(ROT) and M59(ROT') stop in any of the positions 4, 10 or 16, when the operator's position is not occupied. ROT is energised and advances to position 7.

59. When position 5 is reached, ROT' energises and advances to position 7. In positions 1, 7 and 13 of ROT and ROT', the test circuits of the trunks are closed at D1, 7 and 13, or corresponding contacts of ROT or ROT'. Each such contact is individual per trunk.

When both registers are being set up, R'L and R2L have their corresponding Q contacts open. This opens circuit 57, and GPR de-energises.

60. ROT energises and advances to position 10.

61. When arriving in position 8, ROT' energises and advances to position 10, where all the D and similar contacts of both sequences are opened, thus keeping insulated the operator's position, so that no new calls can arrive until the setting up of, at least, one register is completed.

62. The timing arrangement is made inefficient by throwing the NK key, thus short-circuiting at 62 the Q contacts.

Section 59

AUXILIARY CIRCUITS. WESTERN ELECTRIC CO.'S ROTARY SYSTEM

Operation of a Dead Level Circuit.—A level of terminals on a switch to which no working wires are connected is said to be a *dead level*. A circuit is provided, so that when a connection is extended to this in error some response will be obtained. Fig. 127 is a circu t of a dead level on a two-wire second group switch. Should a subscriber dial a digit, that causes the second group switch brush to engage with a level to which no third group switches

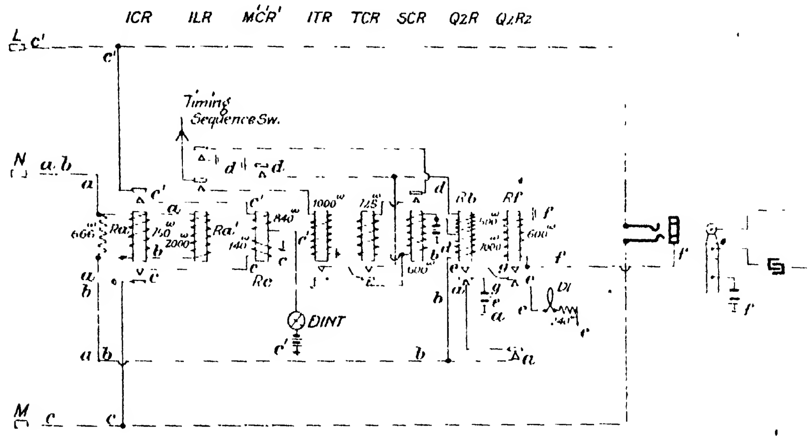


FIG. 127. W. E. CO.'S DEAD-LEVELS CIRCUIT FOR TWO-WIRE TRUNK SELECTORS ONLY.

are connected, then, when the sequence switch advances to position 3, the brush carriage starts to rotate and makes contact with the terminals to which the dead level circuit is connected.

a. A connection is completed to battery.

b. A parallel circuit to *a* in which R*a*(ICR), R*a*'(IER) and R*ab* (SGT'R) (Fig. 125) energise over terminal and brush N, G3 of second group switch. R*b*, being short-circuited, does not energise. M185 (R of second group switch, Fig. 125) advances to position 6 and makes busy the trunk of the dead level in known manner.

c'. Circuit through interrupter DINT, R*c*(M'C"R'), brush L, K6, A wire, fundamental circuit 66, R48, B wire, M6 of second switch and terminal and brush M. When the hundreds impulses have been sent in, the fundamental circuit is closed at M46(R5); DINT closes and R48(SIR) energises, but not R*c*, as its windings are connected differentially. For each opening of DINT the register makes a step, and all the registers are returned to normal, after all digits are in. The register circuit is opened and M16(R') advances to position 10, as previously described.

When M16(R', Fig. 120) arrives in 10, and closes its M10 + 12 and K10 + 12 contacts, circuit 191 is completed over M10 + 12, brush J, B wire, circuit 191 to main spring of L

of M185, then circuit c over terminal M, and a second circuit over corresponding contacts on the A wire (circuit 191), and thence by circuit c' over terminal L. R154 energises, and when DINT opens the circuit of the second winding, Re energises.

d. Rb(Q2R) energises. Circuit a is opened, thus leaving GT2R of second switch, Ra and Ra' in series with the high resistance winding. GT2R and Ra de-energise. SS M185 advances to position 9. R154 de-energises and M16 advances to position 11. Ra' and Rb remain energised.

e. Lamp DL glows to indicate to an operator that a subscriber has dialled a wrong number.

f. A plug is inserted in the corresponding jack and Rf(Q2R2) energises. Circuit d is opened, and the lamp ceases to glow.

g. Rf holding circuit.

The caller is informed of his mistake and re-dials the number. If the caller's receiver is replaced first, the switches release in the normal way, without metering, and Rf and Ra' de-energise. The test terminal is kept busy until the operator restores the key. Rf then de-energises. Should the operator restore her key first, then Rf will remain energised over circuit g. The lamp DL does not glow. When the caller replaces the receiver, the switches are returned to normal.

Should the caller notice and attempt to rectify the mistake by replacing the receiver, the first switch group and register would release. The differential relay Re would not energise, nor Rb, and GT2R of the second switch would remain energised and hold its sequence switch in position 6. To release the second switch, a circuit is completed to a timing sequence switch.

Operation of a Dead Level Circuit where all Switches are in the same Office (Fig. 128).- If on a certain level of the first group switch no trunks are connected, then a dead level circuit takes their place. If a caller dials a wrong first digit, the brushes will find this circuit

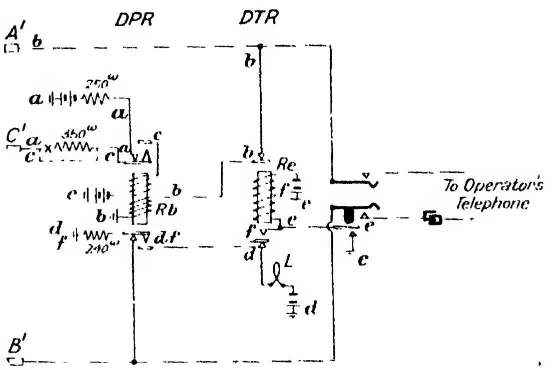


FIG. 128. DEAD-LEVELS CIRCUIT FOR SELECTORS IN SAME OFFICE (W. E. CO.).

(*a*) Ra(ICR) and R16(GTR) energise over brush K, G7 + 12 of first switch. Another circuit short-circuits Rd. M16 advances to position 9.

(*c*) When the caller sends in the thousands impulses, the fundamental circuit 66 is established. Then DINT closes, R48(SIR) energises, but the differential Re does not. At each closing and opening of DINT, the registers step, and when all the impulses are sent in and taken out, the register returns to normal, while M16 advances to position 10. Another circuit for one winding of differential relay Re is completed over circuit 191 and c', M10 + 12, brush J, and for the second winding of Re over DINT brush I, K10 + 12. R154 energises and M16 advances to position 10. When DINT opens, Re energises.

(*d*) R*d* energises and removes the short-circuit about its high resistance winding. R*a* is now in series with the 7,000 ohms winding of R*d* and de-energises. R154 de-energises. M16 then advances to position 11.

(*e*) Lamp CL glows at the operator's desk.

(*f*) The operator answers by moving the corresponding key, and R*f* energises. The lamp CL ceases to glow.

(*g*) Holding circuit of R*f*.

The condenser in the operator's circuit prevents R154 energising, and M16 remains in position 11.

When the caller replaces the receiver, the connection is released, as before described. R*d* de-energises, but the trunk is kept busy until the operator restores the key. R*f* then de-energises and the circuit is ready for a new call.

Operation of a Dead Line Circuit (Fig. 129).—The terminals on a final switch are of a disconnected subscriber are connected to a dead line circuit.

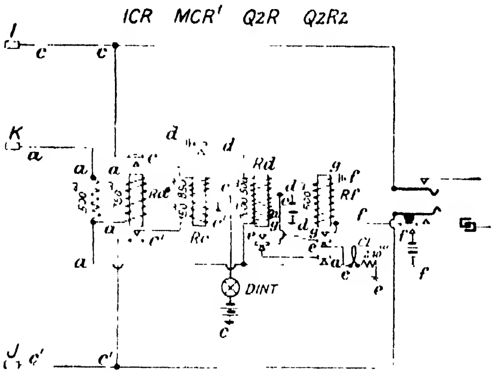


Fig. 129. Dead-line Circuit for Disconnected Subscribers (W. E. Co.)

(*a*) When such a line is called, a test circuit is completed over brush C', thence over circuit 140. R140 energises and advances the sequence switch of the final switch to the ringing position. M103, arriving in position 12, closes its K12 | 14.

(*b*) Circuit 144 is then completed to the brush A', then over circuit *b*. R144 and R*b* energise. R144 advances M103 into the talking position 15.

(*c*) R*b* remains energised in series with R140 and R141.

(*d*) Lamp L glows at desk.

(*e*) The operator depresses the corresponding key, and R*e* energises. The lamp ceases to glow.

(*f*) Holding circuit of R*e*.

R154 does not energise, owing to the condenser in the operator's circuit, and M16 remains in position 11.

When the caller replaces the receiver, the connection releases without metering. When M103 opens its G12 | 17 and H12 | 17, the circuit at the terminal C' is opened and R*b* de-energises. If the operator has not restored her key, R*e* remains energised over *e*. If the operator restores the key before the caller releases, R*e* remains energised over *f*, until the caller does release. The lamp L does not glow.

Section 60

THE WESTERN ELECTRIC CO.'S PANEL SYSTEM

Development.—The development of the so-called panel type automatic system was started by the Western Electric Co., in conjunction with the American Telephone and Telegraph Co., about 12 years ago. The development had for its object the creation of a system particularly suited to large networks. A small equipment was installed in 1912 and operated as part of the New York Telephone Co.'s system. A few years later, two large central office installations were placed in service in Newark. These installations were subjected to the most careful investigation, and, as a result, the system was adopted by the Western Electric Co. in America for large full and semi-automatic networks. A few photographs of the Newark installations are reproduced in the following pages.

The fundamental method of operation, that is, the revertive control of the switches by registers, is the same as in the rotary system. The essential difference, apart from a constructional point of view, lies in the fact that the panel system permits the use of trunk groups of any size up to 100.

PANEL AUTOMATIC APPARATUS

Panel Selector and Finder Frames.—A typical panel selector frame is shown in Fig. 130. The selectors, which are described later, are located in the centre. On each side are placed the associated sequence switches and relays. The capacity of a full frame is 60 selectors, 30 on each side of the frame. The combined capacity of the five multiple banks is 500 lines or junctions.

The finder frame is similar but smaller. The capacity of a finder frame is 60 finders and 100 to 600 junctions, or lines, depending upon the traffic. Finders may be operated with or without sequence switches, depending upon the circuit requirements.

Each row of selector frames is driven by two $\frac{1}{16}$ H.P. or $\frac{1}{8}$ H.P. motors, connected to the shafting through enclosed oil immersed worm drives of highest efficiency. One motor drives the selectors on one side of the frames, and the other motor the selectors on the other side.

Section 61

OPERATION OF LINE-CONNECTING SWITCHES

Selector Switch.—The switching appliance, known as a selector, is a switch capable of making contact with any one of 500 sets of terminals, to which the switch has access. The terminals are assembled in banks (see Fig. 131), one above another on $\frac{1}{8}$ in. vertical spacing, with multiple contacts on a horizontal spacing to accommodate 60 selector switches, 30 on the front face and 30 on the back. The terminals appear before each switch in three vertical rows. The centre row is for the third wire local connection, the outer rows are for tip and ring wire connections. The terminal banks are built up of flat strips of brass, having

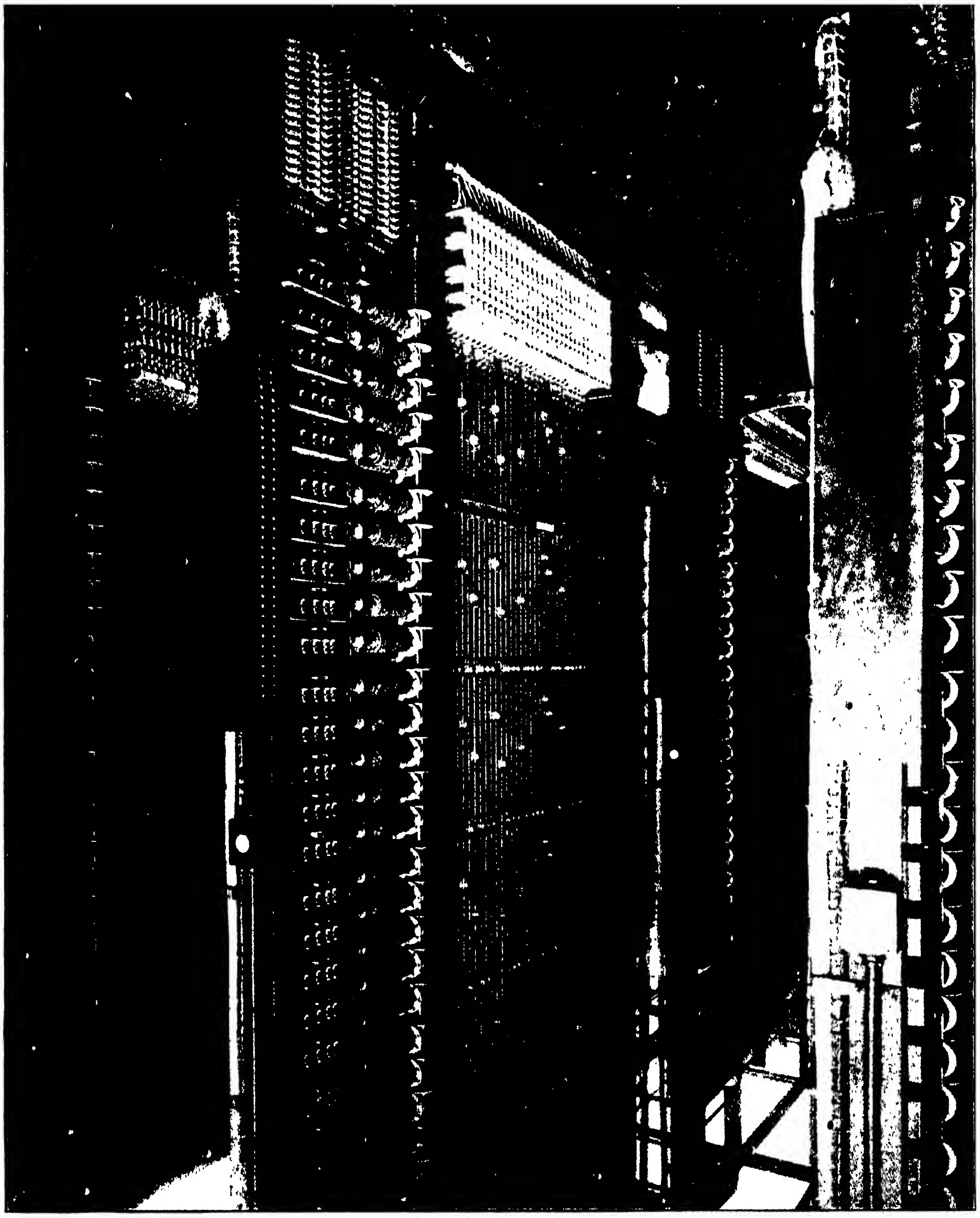


FIG. 130.—TYPICAL PANEL SELECTOR FRAME.

projecting lugs along each edge, which form the multiple contact points or terminals. Strips of insulating material are placed between the brass strips. There are 100 terminals in each vertical row. There are three rows of soldering tabs at each end of the bank (shown in Fig. 132), by means of which the brass strips forming the multiple contacts are connected

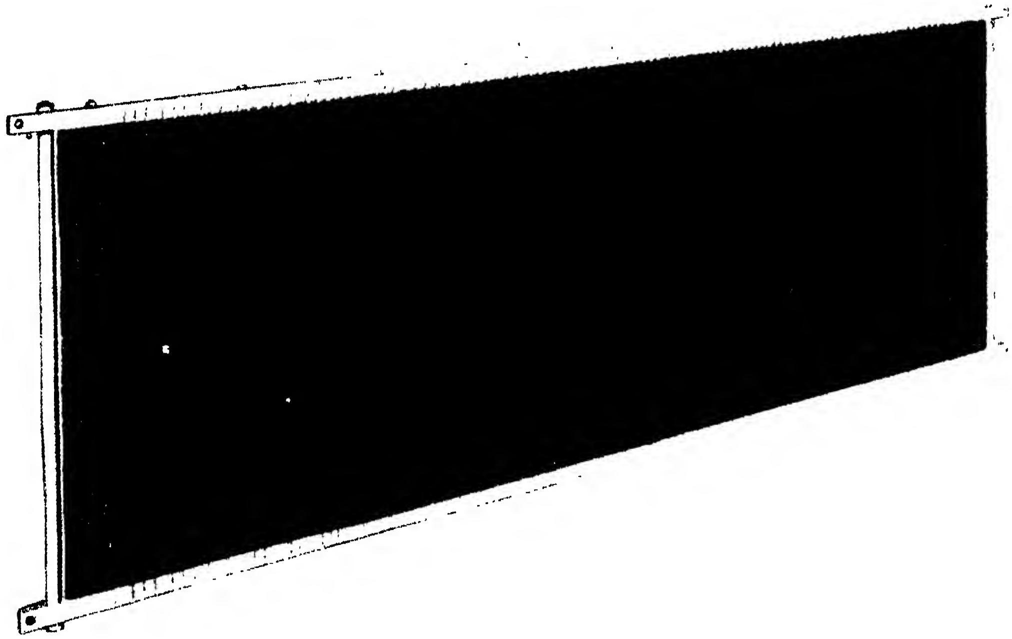


FIG. 131.—A BANK OF TERMINALS IN PANEL SYSTEM.

FIG. 132. A STRIP OF SOLDERING TABS FOR A BANK.

with the line and local circuits. A close examination of the bank will show the vertical rows arranged in groups of three. As explained above, each group constitutes the terminals for one switch. Five terminal banks are mounted in a frame, one above another, so that there will be a total of 500 terminals in each vertical row, and all the terminals in a row will be accessible to a selector switch, which is mounted in the same frame with the banks.

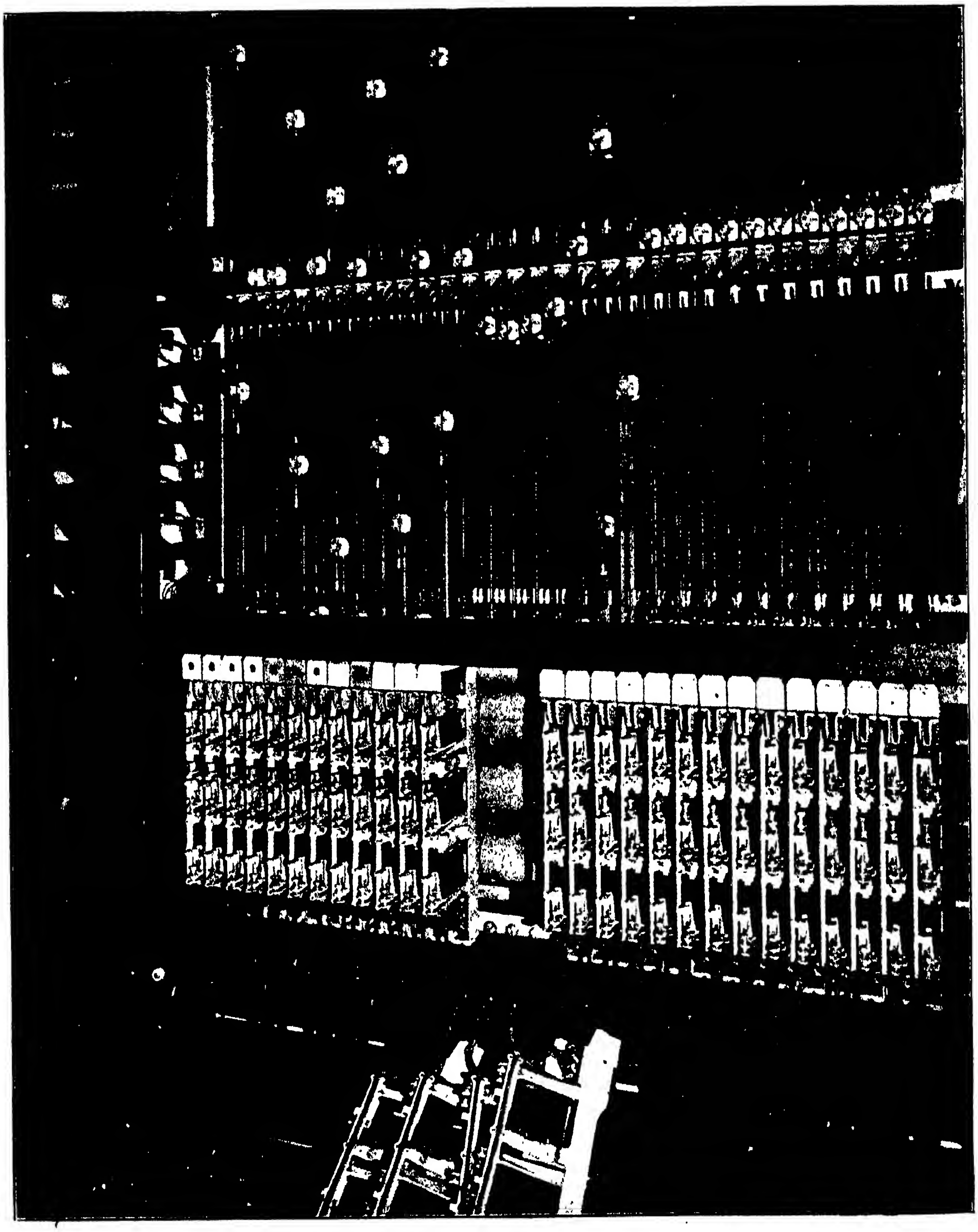


Fig. 133.—Detail View of Panel Frame and Selectors.

As explained above, there are enough vertical rows to accommodate 30 selector switches mounted on the front and 30 on the back of the frame. They are mounted on 1⅛ in. centres, the entire frame being 42 in. in horizontal length and 10½ ft. high. The selector switch has five multiple brushes (see Fig. 133) mounted on a long vertical brush support or shaft, made of brass tubing ¼ in. in diameter. The contact springs of the brushes sweep up and down over the terminals in the terminal banks, one brush for each bank. The arrangement of the brush supports and brushes of the 30 switches mounted on one side of a frame can be readily seen in Fig. 133. The multiple banks are behind the brush supports, but do not show very well in the picture. Eight of the selector switches shown have their brushes in position to make contact with the terminals. The contact springs of the brushes span the terminals, the inner two springs making contact along the edge on each side of terminals in the centre row, and the outer springs making contact along the outer edge of the terminals in the outer rows.

A rack is fastened to the lower end of the brush support, for the purpose of giving an up and down movement to the brushes. This rack is made of a strip of bronze 21 in. long, and ⅝ in. wide. It has a number of slots forming teeth along the centre. These slots are ¼ in. and $\frac{1}{16}$ in. high, and except the upper five, are on ⅛ in. centres, corresponding with vertical spacing of multiple terminals. In Figs. 133, the switches which have moved up to make contact with the terminals, show the racks fastened to the lower end of the brush support. The four switches in the centre have their racks removed. The vertical movement is accomplished by means of a magnetic clutch pressing the rack against constantly revolving cork-faced rolls. These rolls are mounted at the bottom of the selector frame, extending the whole length of the frame, and are kept constantly revolving by an electric motor. Fig. 134 shows the arrangement of clutches mounted on a frame. The cork-faced rolls behind them can be seen where the clutches of four switches in the centre have been removed. The frame shown in the picture has three rolls in front and three in the back. The two lower rolls on each side revolve in a direction that gives the rack an upward motion when pressed against them The top rolls revolve in the opposite direction, to give the racks a downward movement, which is used to return the brush support to its normal position when a call is disconnected. The middle and top rolls on each side revolve at a speed which will make the multiple brushes sweep over the terminals at the rate of 60 per second. The bottom

FIG. 134. CLUTCH MAGNETS IN FRAME. PANEL SYSTEM.

roll drives the brushes at a slower speed, and is used only for unit selection in final selectors.

The switches used in district, office, and incoming circuits are arranged for only one up-drive speed. Fig. 134 shows the construction of the clutch for a selector with single

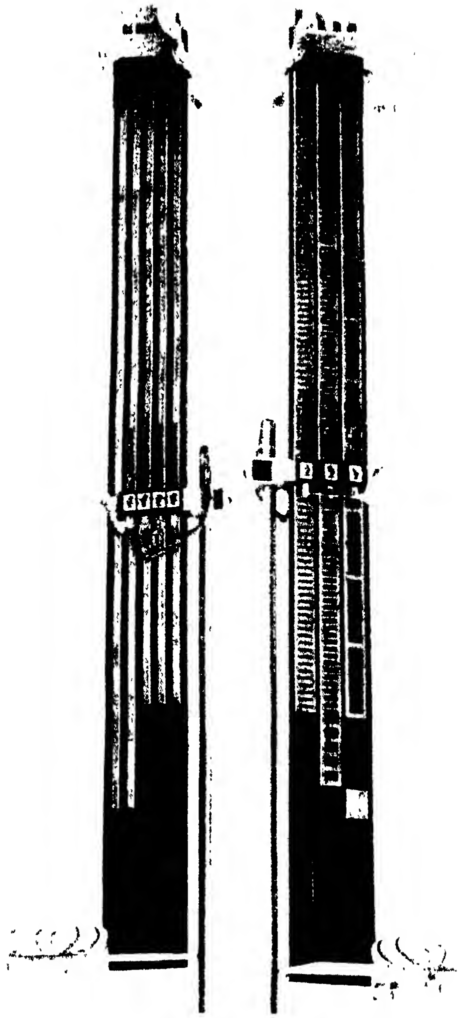


FIG. 135.—FRONT AND REAR VIEWS OF COMMUTATOR. PANEL SYSTEM.

up drive speed. The lowest magnet, when energised, pulls up the armature shown below the magnet. The armature, through a heavy retractile spring, pulls up a bell crank lever, on the short arm of which is mounted a small roller behind the magnet coils. This roller presses against the rack and so presses the rack against the revolving cork-faced roll. The

centre magnet shown in Fig. 134 is for the down drive The upper magnet is called the trip magnet; its function will be described later.

In the clutch is a pawl, which slips over the teeth in the rack as the rack moves upward. Its object is to hold the rack up and keep it from falling when the pressure against the lower roll is removed. The height of the multiple banks is so adjusted that when the rack is resting on the pawl, by its being engaged in one of the teeth of the rack, the multiple brush contact springs will centre on the corresponding terminals. When the down-drive magnet is energised, the pawl is pulled away from the teeth, and the rack is free to take a downward movement from the upper roll.

Each selector switch has mounted in the frame, above the top multiple bank, a commutator. A brush, fastened to the upper end of the brush support, sweeps over the segments

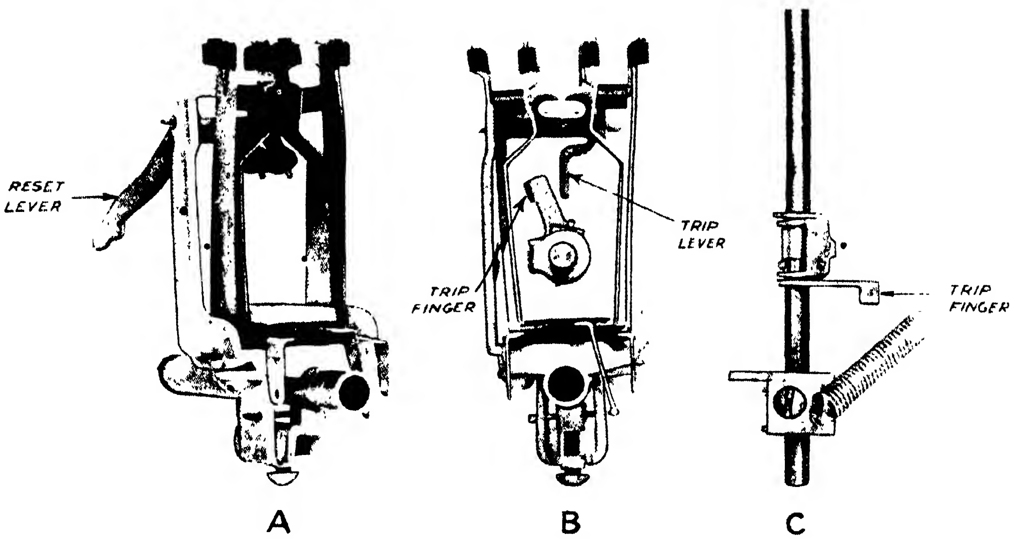


FIG. 136. BRUSH AND TRIP DEVICE. PANEL SYSTEM

of this commutator with the vertical movement of the brush support. A view of this commutator with brush mounted at the top of the brush support is shown on Fig. 135.

The contact springs of the multiple brushes in their normal position are spread apart to prevent their touching the terminals of the multiple terminal bank as the brushes sweep up and down. There is a small tripping lever on the brush which, when pulled down, allows the springs to press against the terminals. The brush (B) in the centre of Fig. 136 shows its contact springs in the normal or reset condition. The brush (A) on the left shows its contact springs in the trip condition. The tripping lever can be seen on the centre brush, just below the inner two contact shoes and on a line between them. When a brush is tripped, it will remain so until restored to its normal condition by the action of a reset lever. This lever can be seen on the left brush, shown in Fig. 136. With the downward movement of the brush, just before the brush support reaches its normal position, the resetting lever

strikes against a bearing of the brush support, giving an upward pressure on the lever, which resets the brush springs. At C is shown details of the trip rod and finger.

From the above it will be seen that in order to select any one of the 500 lines to which the selector has access, it is first necessary to trip one of the five brushes and then move the brush up to the terminal desired. Directly behind the brush support, between it and the terminal bank, is a long vertical rod considerably smaller in diameter than the brush support. This is called the trip rod. In Fig. 133 the trip rods of the selectors on the left end of the frame can be seen behind the brush supports. Those on the right end are hidden by the brush supports. The trip rod is free in its bearings and can be rotated about its axis. A retractile spring, holding a finger at the bottom of the rod against a stop, holds it in its normal position. There are five small trip fingers on the rod, so placed that when the trip rod is in its normal position the trip levers on the brushes will pass by on one side of the fingers. as the brushes move up and down, without touching the fingers. Fig. 136 shows a trip finger (C) to the right of the multiple brushes, and the relative position of a trip finger, with a trip lever, is shown in the B view of the right brush, which is a view looking directly down on the brush and finger, with the trip rod in its normal position. When the trip rod is rotated through an arc of about 30 degrees, the trip levers pass by on the other side of the fingers without touching. The trip fingers are made so that they can rotate on the trip rod, independent of the rotation of the rod itself. They are held by means of a retractile spring against a stop rigidly fastened to the rod. The lower trip finger is located on the rod at such a height that, when the rack rests on the pawl with its highest tooth engaging the pawl, the finger is directly opposite the trip lever of the brush. If, when in this position, the trip rod is rotated, the finger will engage the trip lever and be held against it by its retractile spring. Now, if the clutch is energised to drive the brush support upward, the trip finger, having no vertical motion, will give a downward pull on the trip lever and so trip the first brush, and allow its contact springs to press against the multiple bank terminals, as soon as the brush is carried high enough to bring the terminals in its path. The second trip finger is located so that it can engage the trip lever of the second brush when the rack is resting on the pawl. If the trip rod is rotated with the brush support in this position, the first trip finger will pass under the trip lever of the first brush without touching, while the second trip finger will be held against the trip lever of the second brush.

Thus it will be seen that any one of the five brushes can be tripped by first raising the brush support to the required height, then letting it rest while the trip rod is rotated, and while the rod is in its rotated position, moving the brush support upward again. The height to which the brush support is first raised determines which brush will be engaged by a trip finger. The trip fingers below the one engaging a brush will pass under the corresponding trip levers without touching, when the trip rod is rotated, while those above will pass above corresponding trip levers. The rotating movement of the trip rod is accomplished by means of a lever pushing against the finger at the bottom of the rod, and acting against the retractile spring, moving the rod through an arc of about 30 degrees. The movement of this lever is controlled by a separate magnet, located on top of the clutch. (See Fig. 134.)

The commutator (see Fig. 135) is composed of an insulating compound, into which brass segments have been moulded. On one side of the commutator are three feed bars, through which electrical connection is made to the multiple brushes. The commutator brush springs, and the multiple brush springs, are connected by wires running through the inside of the tube, which forms the brush support, these wires being brought out at each brush. There is

another feed bar on the same side, which is connected to the central office battery, and its corresponding contact spring is strapped to the contact springs on the other side of the commutator. As the latter contact springs travel over the segments, the central office battery is fed to them, one after another, thus forming an interrupter. The segments in the path of each spring are, by their construction, joined together electrically, but insulated from the segments in the paths of other springs. Each spring, with its corresponding segments, thus forms a separate interrupter. The object of these interrupters is to feed battery impulses over the selecting circuit to the sender, the number of impulses being determined by the number of segments travelled over by the brush as it moves upwards. The segments are located vertically, so that they bear a very definite relation to the height the multiple brushes have travelled. The interrupter used while brush selection takes place, called the A interrupter, has its segments so located that when the brush support is in the position to trip the first brush one impulse will have been sent. When in position to trip the second brush, two impulses will have been sent, and so on. The spacing of the segments is the same as the first five teeth on the rack. The spacing of the segments in the other interrupters will be determined by the circuit in which the selector is to be used. As an illustration, in the final circuit, after brush selection has been made, the next selection is for tens. Here the interrupter used has its segments spaced so as to give one impulse for every 10 terminals travelled over by the multiple brushes. The interrupter used in units selection is spaced to give an impulse, for every terminal passed over by the multiple brushes, while the selection is taking place.

It should be noted that one of the characteristics of this system is, that the selector switch depends for its movement on mechanical power, separate from, but controlled by the selecting circuits. The impulses, being created by the movement of the selector as its brushes move upward, measure the distance the brushes travel. As they are transmitted over the selecting circuit to the sender apparatus, they are counted by it, and when the desired number have been received, a circuit condition is established which releases the up-drive magnetic clutch on the selector.

Finder Switch.—The finder switch is similar to the selector switch, described in the preceding paragraph, but trip rods are not necessary since the brushes rest in permanent contact with the terminals of the multiple banks. Furthermore, the finder switch has but one set of brushes, instead of five, which set of brushes has access to a maximum of 100 lines or junctions.

Section 62

CONTROLLING SWITCHES

Sequence Switch.—This appliance, shown in Fig. 137, is used to accomplish in the circuits what could be done with a large number of relays. It has a shaft which can be rotated, and on which are assembled about $\frac{3}{8}$ in. apart a number of cams. Each cam consists of two discs of phosphor bronze, separated by a disc of fibre. The three discs are securely riveted together and rigidly secured to, but insulated from the shaft. Pressing against the

flat sides of each cam are four phosphor bronze contact springs, two on each face, all making contact on the same radial line. By cutting away the bronze disc in the path of a spring, that particular spring will rest on fibre instead of metal, and so open its electrical contact. Thus, it can be readily seen that any combination of electrical connections between the four springs can be obtained for any period of one revolution by cutting away or leaving the part of the metal disc which passes under the contact springs as the cam rotates. The cams are divided into 18 equal sectors of 20 degrees. Each sector is known as a position.

The cams are assembled on the shaft with the centre of the first position of all cams in line. When the contact springs are on the radial line through the centre of this position, the switch is said to be in position 1. When on the radial line through the centre of the second position, the switch is in position 2, and so on for the 18 positions. The collar on the

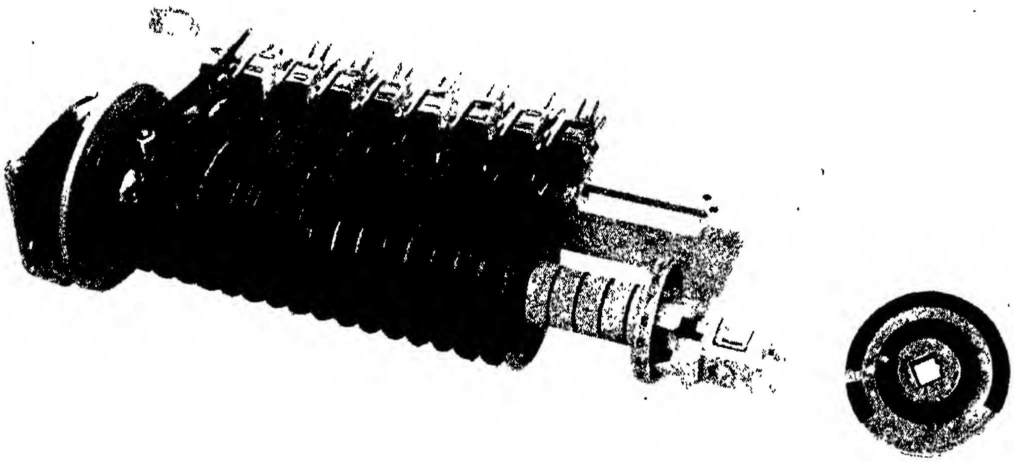


FIG. 137. SEQUENCE SWITCH FOR W. E. CO.'S PANEL SYSTEM.

right of the shaft and the pointer on the right end of the frame indicate at any time the position in which the switch rests. The switch shown in Fig. 137 is in position 4.

The switch is mounted with its shaft horizontal, and at the left end of the shaft is an iron disc, fastened to the shaft by means of a flexible spider. Immediately to the left of the switch, mounted in the same frame on which the switches are mounted, is a constantly revolving vertical shaft. On this shaft is rigidly fastened an iron driving disc for each sequence switch. Fig. 137 shows the manner of mounting the sequence switches and their driving shaft. The outer edge of a driving disc just clears the side surface of the disc on the sequence switch shaft, near the outer edge of the latter. Between the vertical shaft and the disc on the sequence switch is an electromagnet fastened to the frame of the switch. When this magnet, called the rotating magnet, is energised, the disc on the switch is pulled against the driving disc, and a rotating movement is imparted to the switch by the friction of the contacting surfaces of the two discs.

The winding of the magnet is wired to different contact springs, according to the require-

ments of the circuit in which it is used. In a given position the current to the magnet is fed through one of these contact springs and, by this means, the switch is started rotating out of the position. The object of this spring is merely to start the switch out of the position, its contact being opened before reaching the next position. There must be some means then of keeping the switch revolving by means of a special cam. This cam has a spring, wired to the winding of the rotating magnet, which keeps the magnet energised when its contact with the cam is closed. The cam is cut to open this contact when the switch is centered in a position, but it is closed between positions. There is also a mechanical centring device, made by having a roller spring drop into indentations along the outer edge of the special cam. If the circuit conditions do not require the sequence switch to stop in any given position, the special cam is not cut to have its spring open in this position, thus keeping the rotating magnet energised and causing the cam to revolve right through the position without stopping.

Section 63

TRANSMISSION

The local transmission circuit, for connecting within the inner zone, will include the manufacturer's standard repeating coil, and the potential of the battery supply will be the standard 23 volts. The repeating coil forms part of the connection circuit. On junction calls, both in and out, an additional repeating coil will be introduced at the terminating end of the junction, as in present manual practice.

The toll switching trunks will include a repeating coil, which will be served by a potential of 48 volts.

When a call is established through a semi-suburban position, the repeating coil in the connection circuit is cut out and, in place thereof, a repeating coil forming part of the first selector junction from the suburban position is inserted in the circuit. This repeating coil will be served by a booster battery of 48 volts.

In order that special junctions, if necessary, may be provided for a portion, or all, of the tandem junctions, a separate frame will be provided for the junctions from the suburban position. The junctions on this frame may be a multiple of those appearing on the local frames, or all or a portion of them may be independent of the local junctions, as above stated.

The special requirements of loaded junction circuits and repeaters may be met at any future time by introducing into the other switching and suburban junctions such changes as may be necessary.

Fig. 138 is a general view of an installation of the panel system

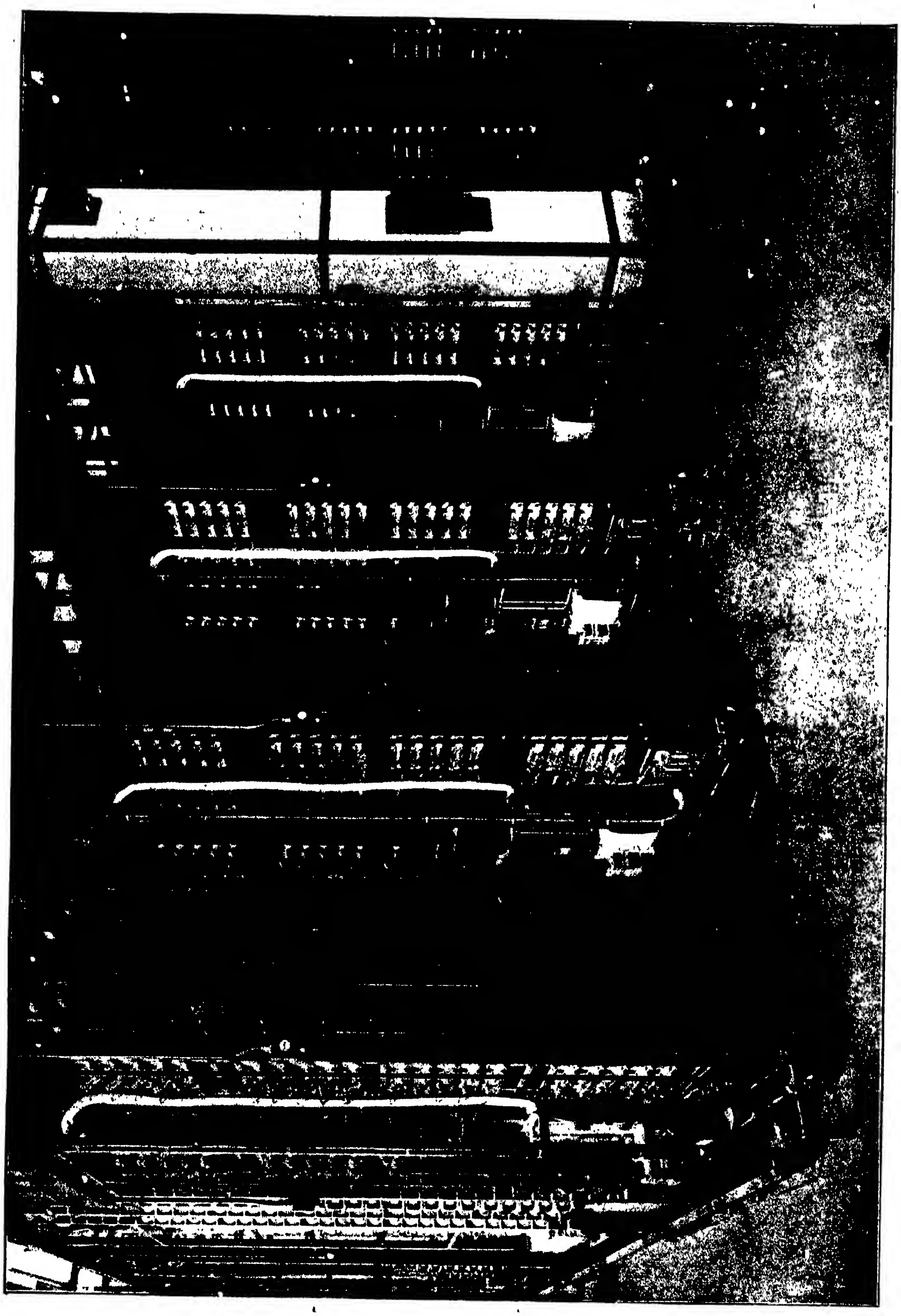


Fig. 138.—General View of a Panel System Installation.

Section 64

ADVANTAGES CLAIMED FOR THE PANEL SYSTEM

Some of the essential features of the system, and the advantages derived therefrom (for both full and semi-automatic operation), may be briefly stated as follows :—

Power Drive.—Exceptionally robust apparatus.

Apparatus of greater range and usefulness—witness the 50 to 100 junctions per bank, and the possibilities afforded by the sequence switch.

Reliable and powerful contacts.

Freedom from vibration. It is known that vibration has a very detrimental effect on contacts and on the permanency of adjustment.

Minimum maintenance, due to said robust construction and permanency of adjustment.

Registers.—Greater accuracy, revertive control, continuous hunting.

Converting lost calls into delayed calls, and increasing the ability of the exchange to handle heavy overloads without serious effect on service.

Permits hunting over large groups without decreasing the speed of dialling.

Subscriber's dial impulses into registers located in the associated office. The impulses are of uniform strength and accuracy, and are not affected by the number of branch offices, or satellites, or distances between them.

Subscriber may dial at maximum speed during the busy hour.

Indefinite repetition of impulses without decrease in accuracy, due to the fact that successive trunk groups need not operate in synchronism with the calling subscriber's dial.

Translation, permitting the grouping of more than 100 lines or junctions on a single switch.

Facilitates grouping of offices of different sizes.

Second and third group switches may be suppressed in any exchange, when they are not needed.

Takes into consideration the first or controlling digits of the number and handles the call accordingly.

Sequence Switch.—Great flexibility in meeting difficult circuit conditions.

No power required to maintain a sequence switch in any position.

Positive and accurate contacts of uniform tension.

Design.—There are no parts which can be termed perishable.

Every part has a long life.

Any part easily removed, repaired, or adjusted.

Every piece of apparatus is adjusted, both mechanically and electrically, to prescribed specifications.

Each individual piece may be adjusted independently, and when a combination of them are assembled, the circuit is in operative condition with wide margins of safety in every direction.

Double connection practically impossible. A line or junction is made busy ·001″ or ·002″ after the instant of testing.

Wide limits in battery potential permissible.

All margins of safety are maintained with any potential between 44 and 52 volts. A failure will not occur, in most cases, between limits of 40 volts and 55 volts.

Apparatus is self-adjusting, that is, unavoidable wear will not throw the apparatus out of adjustment.

Service and Traffic.—Affords full and complete supervision of all semi-automatic connections.

Permits every stage of a call to be investigated.

Provides for various systems of automatic metering.

Permits distribution of junction traffic to be accurately recorded.

Permits the operators' handling time and subscribers' drag to be analysed.

Permits the average holding time to be determined at any junction point.

Permits simple re-distribution of junctions to meet the variations in traffic.

Reduces the effect of false calls, and subscribers' drag, to a minimum.

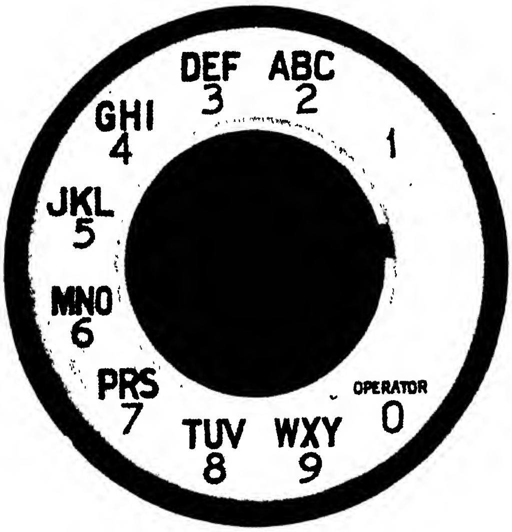


FIG. 139. DIAL WITH LETTERS AND FIGURES AS PROPOSED FOR PANEL SYSTEM, LONDON.

Full Automatic Dialling. The subscriber's dial does not require close adjustment.

Any speed between 9 and 13 steps per second is permissible. A dial, when once adjusted to normal speed, will remain between these limits for a long time.

No special dial speed adjusting apparatus is required at the central office.

With a little practice, it is possible to judge the speed of a dial by eye with sufficient accuracy for all practical purposes.

A dial adjusted on a telephone in the store room before installation will not require re-adjustment when the set is installed.

From numerous observations it may be said that the dialling tone is heard on 99 per cent. of the calls in 1·5 second or less; in other words, about as soon as the receiver is placed against the ear. After the dialling tone has been heard, it is impossible to dial too rapidly.

This is an important advantage, peculiar to a system provided with registers, and is due to the fact that a register does not have to hunt for an idle trunk. It merely has to record the number dialled. The subsequent time required for hunting, and this may be noticeable during the busy hour, has nothing to do with dialling. To illustrate the advantage of the system over a system without registers, attention is called to the following table, which is based upon the result of numerous observations on a modern automatic system without registers :—

Trunks busy.	Failure occurs when dialling Digits –
1	1
2	1, 2
3	1, 2, 3
4	1, 2, 3, 4
5	1, 2, 3, 4, 5, 6
6	1, 2, 3, 4, 5, 6, 7, 8
7	1, 2, 3, 4, 5, 6, 7, 8, 9, 0
8	1, 2, 3, 4, 5, 6, 7, 8, 9, 0
9	1, 2, 3, 4, 5, 6, 7, 8, 9, 0

It will be seen that a failure occurred when the digits 1, 1, 1, etc. were dialled as rapidly as possible, each time a selector had to hunt for the second trunk, that is, when the first trunk only was busy. A failure occurred when dialling very rapidly a series of digits 2, when the first two trunks were busy. Similarly, a failure occurred when dialling very rapidly a series of digits 3, when the first three trunks were busy. In fact, no matter what digit was dialled, a failure was bound to occur, if dialling was done too rapidly, when the first seven trunks were busy. This table illustrates very clearly the reason why a large group of trunks cannot be used per level in a system not provided with registers.

The above table indicates very clearly the absence of any margin at the time element in a system not employing registers. Anything which tends to increase the time of hunting will increase the number of lost calls, or what amounts to the same thing, will reduce the efficiency of the already small trunk group. In this connection, particular attention is again called to the detrimental effect on service, which the introduction of concentration switches would have, in case they were used to increase the size of trunk groups in a system not employing registers.

Section 65

WESTERN ELECTRIC CO.'S PANEL SYSTEM FOR LONDON

The British Post Office have arranged to install a trial exchange office on the panel system in G.P.O. (South) in the building containing the present "Central" and "City" offices. The new equipment will take all new lines in the area, and thereby relieve the present

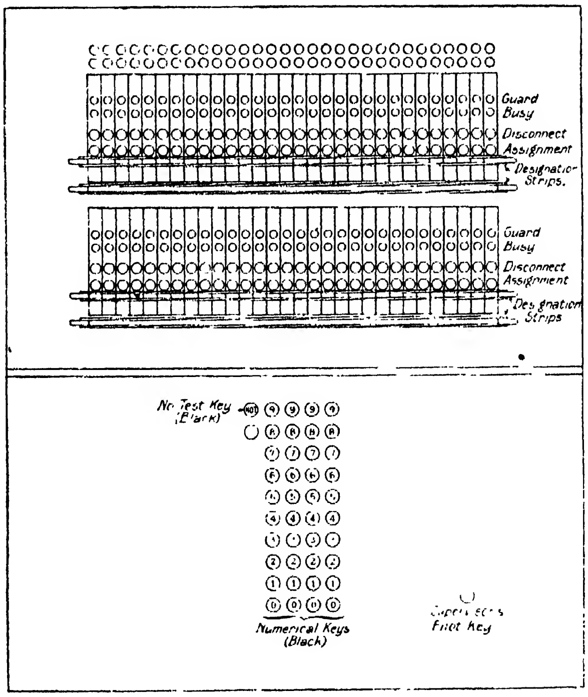


FIG. 140.—PANEL SYSTEM. B POSITION KEYBOARD FOR MANUAL WORKING.

manual switchboards, but, should the trial be successful, the existing equipments will gradually be replaced. Other offices in London are also contemplated.

The calling numbers will be on a basis of a seven-digit number, but, to assist memorising and to make the directory number suitable for manual and automatic working during the long transition period, the first three digits will be replaced by letters. The three letters will be a part of the name of an office, and will be followed by four figures. The letters to be used in dialling will be printed in bold type, as MAYfair 2,163, CENtral 7,880, VICtoria 3,826, and the like. The dial will be marked as shown in Fig. 139. By an examination of the dial it will be seen that MAY of Mayfair is equivalent to dialling 629, and these letters dialled would call into the Mayfair office, and the following four figures would call the particular line in that office if it were an automatic office. While it remains a manual office the

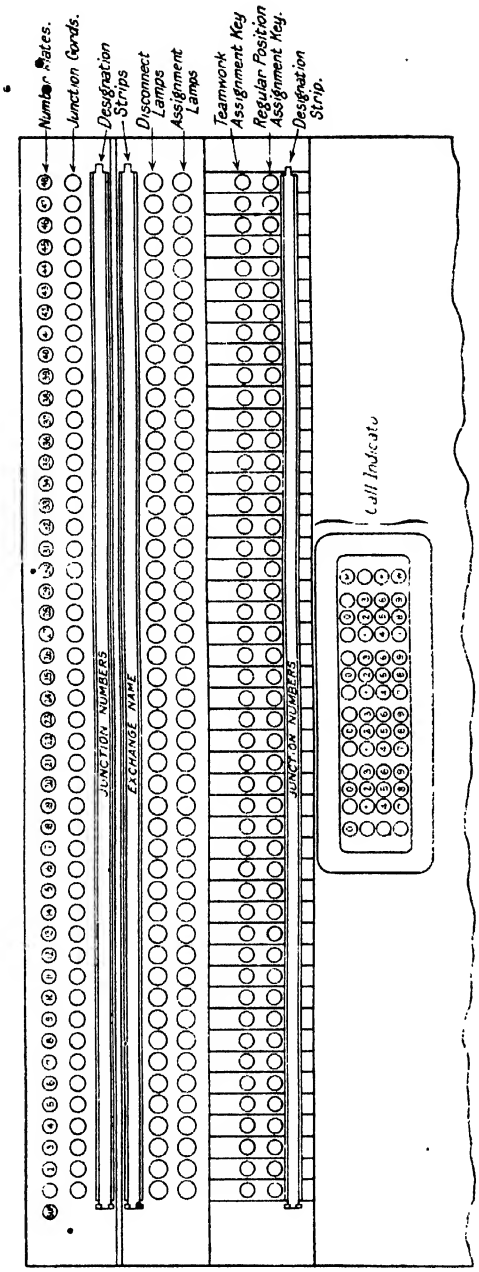


FIG. 141.—PANEL SYSTEM B POSITION FOR CARRIAGE CALLS.

digits 2,163 will actuate special apparatus in connection with one, or more special positions, and glow four lamps to indicate the number required to be set up manually, in the manner described in Section 58 on "Carriage Call" working. Fig. 141 shows how such a B position keyboard is arranged.

When for special reasons manual offices are not equipped with dialling devices the calls

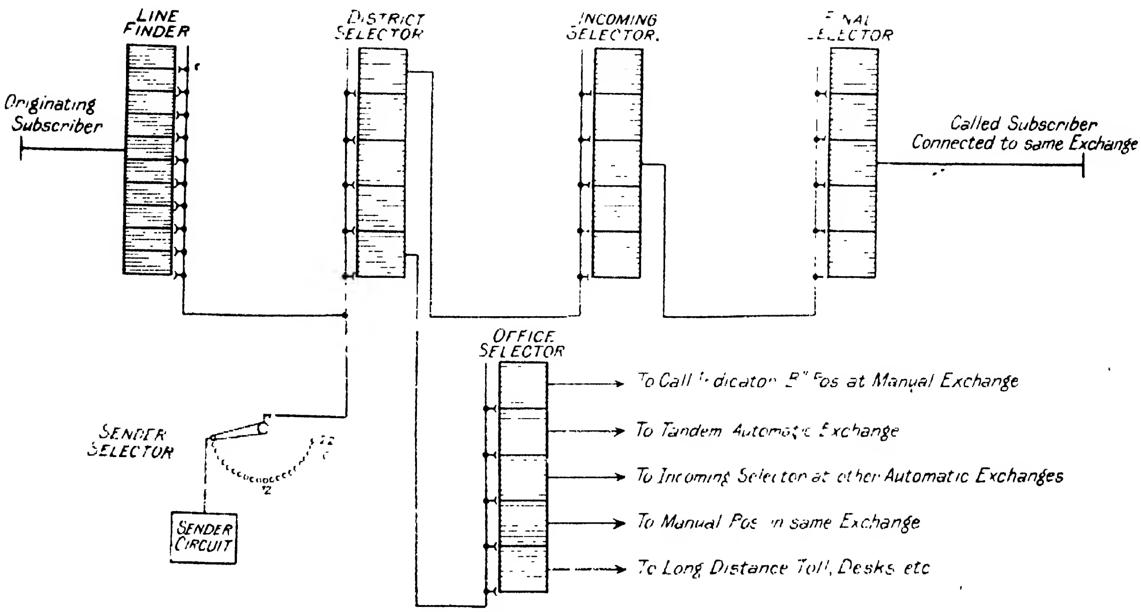


FIG. 142.—W. E. CO'S. PANEL SYSTEM. SWITCHES INVOLVED IN A CONNECTION.

from manual offices will be passed over order wires to a special B position in the automatic office, where an operator will set up the number desired on keys (more particularly described in Vol. 2), to complete the connection automatically. A suitable keyboard is shown in Fig. 140.

The capacity of each automatic office will be 10,000 lines. The switches involved in a connection may be as shown in Fig. 142.

Section 66

THE WESTERN ELECTRIC CO.'S PANEL SYSTEM

Apparatus and Circuits.—Unfortunately circuits of the commercial system are not yet available for publication, but an endeavour has been made to make good this shortcoming by reproducing diagrams from the available patent specifications. These will enable the reader to understand the fundamental principles, at least, and give a good idea of how certain results can be attained, although it may be found necessary afterwards to modify the opinions formed to some extent, when the official circuits become known.

The circuits, generally, follow the lines of the rotary system.

The circuits are built up and modified from time to time as required by sequence switches, a horizontal type, however, being used instead of the vertical type shown in Fig. 93. The dial impulses from the subscriber are received on registers, as shown in Fig. 124, and these pass the complement of the impulses to the switches which, on the revertive control principle, send back impulses to cause the register to give up its impulses one by one until zero is reached, when the switches are in the operative position. Figs. 144–150 show a panel switch in considerable detail. The group switches and the final switch are of 500-lines capacity. The former automatically selects an idle line in groups which may have as many as 100 lines in each. Banks are provided for five such groups, the banks being suitable for sixty switches working thereon, thirty on each face. The final switches are of 500-lines capacity and, by these, access is given to groups of 1,000 subscribers' lines. This result would appear to be attained, in a manner similar to that by which the rotary switches select one or other of two groups of 100-lines, that is, by translation, the plus or minus train of impulses determining which of two groups of final switches are to be used, when the call is for an odd or even hundreds number. The line switches are of the calling line finder type as before, but like the other switches these have vertical motion only. Details are shown in which one of a plurality of brushes is tripped, and that for the group only in which the calling line is located. Metering or registering of effective calls has received careful consideration, and a circuit is given showing how three kinds of services are manipulated automatically.

It is expected that further details will be available for Vol. 2.

Section 67

A WESTERN ELECTRIC CO.'S 500-LINE PANEL SWITCH.

One form of this is shown in Figs. 144–150. This resembles the commercial forms, but does not necessarily agree in detail. It consists of a vertical shaft carrying a plurality of sets of wipers one for each main group of terminals of 100 lines. The sets of wipers are connected in parallel. The shaft is operated by three driving pulleys, each capable of being clutched electromagnetically to a continuously rotating shaft. By one pulley the shaft is lifted at a comparatively high rate of speed over groups of 10 sets of terminals, by another

W. E. CO.'S PANEL SYSTEM. SWITCH OPERATING MAGNETS.

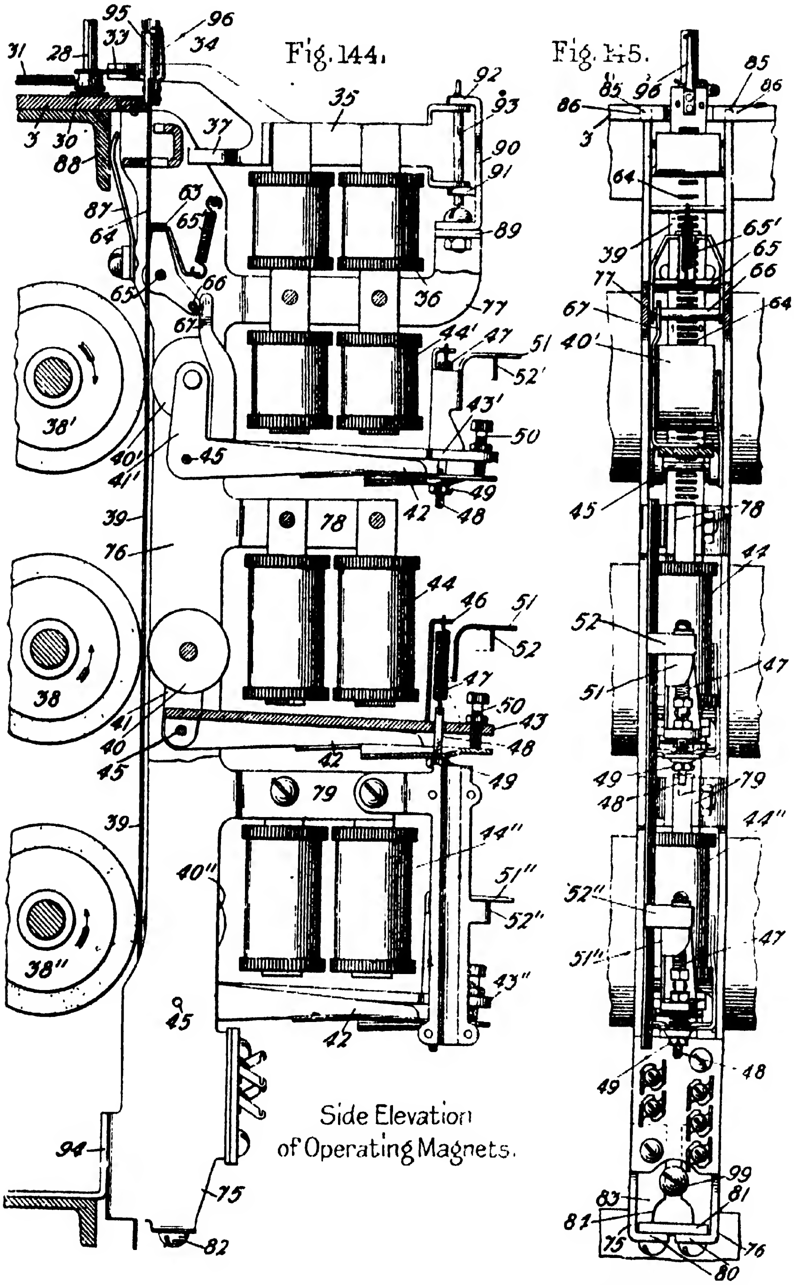


Fig. 144. Side Elevation of Operating Magnets.

Fig. 145. Front Elevation.

at slow speed over single sets of terminals to the line wanted, and by the third the shaft is returned to normal. The shaft is raised by an extension rod which run between a continuously rotating driving pulley and an " idler " pulley, electromagnetically controlled, to clamp the rod between the two pulleys. The shaft is kept in the operative position by a toothed rack on the driving rod (see Fig. 146).

A second parallel shaft carries the tripping devices which bring a particular set of wipers into engagement. These are so spaced that when one is in use all the others are free to pass the triggers. This shaft is rotated sufficiently by an electromagnet (45).

Above the shaft is fitted an interrupter plate (Fig. 147) on which brushes make contact. Fig. 148 shows a cross-section of this on the line 6 6 on Fig. 147.

The line terminals are double ended so that they may be engaged by wipers of other shafts placed on the rear face. Fig. 149 shows this in detail with a plan of the wipers, etc. The upper part shows a set of wipers free from, and the lower part a set of wipers in engagement with, the line terminals. Fig. 150 shows a perspective view of the wipers and the tripping device. When the shaft is lifted, the wiper engaging ends pass freely between the lines of terminals. When the shaft comes to rest, and the trip device is operated, the wipers by their own resiliency move inwards and make contact with the terminals. The two inner wipers make contact with the same terminal.

The slots in the driving rod form a scale on which the position of the shaft may be read, so that an attendant can see at a glance the relative position of the driving rod and the shaft.

The automatic coupling and driving device is formed as a unit which can be readily detached and replaced by simply loosening one screw.

Further details will be described in the schedule of parts which follow, the numbers on the left being the reference designations of the illustrations.

1. Wiper shaft.

2. Guide sleeves for shaft.

3. Frame.

4 and 5. Wiper carrier parts clamped to the shaft.

6 and 7. Clamping screws.

8, 9, 10, 11. Resilient wipers insulated from carrier. By the resiliency of the springs, 8 and 9 are forced towards 10 and 11.

12. Insulated shoes on wipers.

13. Insulations to preserve space relationship.

14, 15, 16. Set of line terminals. Wipers 8 and 9 both engage with terminal 15.

17. Wiper soldering terminals. Connections to these are carried in the tubular shaft.

18 and 19. A pair of arms extending from clamp 4.

20. Pivot pin carried by 18, 19.

21 and 22. Oblong plates fixed to pivot 20.

23. Rollers of insulating material fitted between opposite ends of 21 and 22.

24. Trip member formed by pivot pin 20, bent at right angles.

25. Restoring roller on 24.

26 and 27. Integral lugs to limit the backward and forward movement of 24. When lever 24 is in engagement with stop 27, the rollers 23 will engage the wipers 9 and 10 respectively, and the wipers of the set will be forced to the inoperative position (see upper half of Fig. 149). The pressure of the wipers on the rollers will tend to further clockwise rotation and prevent accidental release. Upon slight anti-clockwise rotation of the trip device, the

W. E. CO.'S PANEL SYSTEM, ONE FORM OF 500-LINE SWITCH.

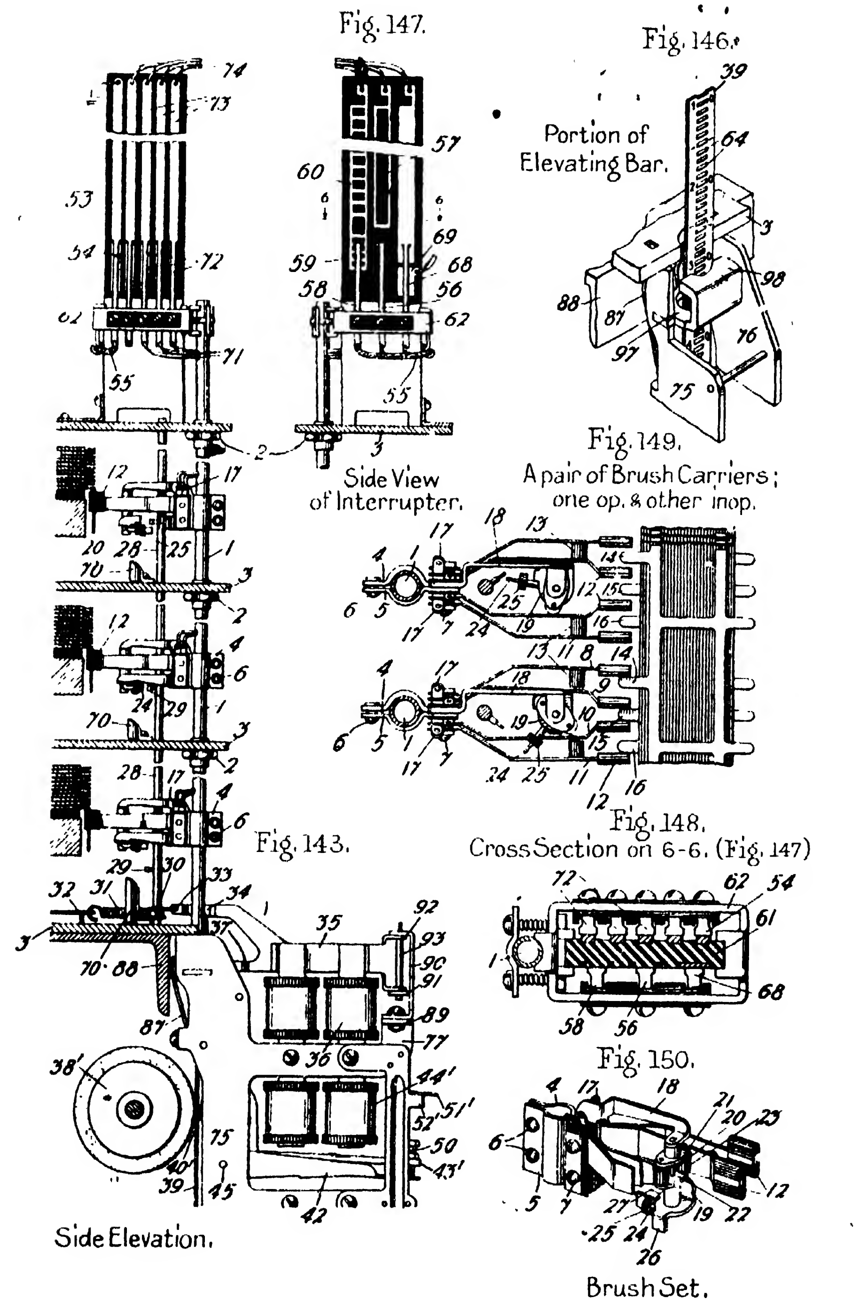


Fig. 147. Side View of Interrupter.

Fig. 146. Portion of Elevating Bar.

Fig. 149. A pair of Brush Carriers; one op. & other inop.

Fig. 143. Side Elevation.

Fig. 148. Cross Section on 6-6. (Fig. 147)

Fig. 150. Brush Set.

wiper pressure will force it to the position shown in the lower half of Fig. 149, when the wipers will engage with the terminals.

28. Trip rod rotatively mounted in frame 3.

29. Trip pins in alignment on the rod at progressively increasing distances from the normal position of 24, and arranged slightly to one side of the line of travel of 24.

If the wiper shaft is moved upwards until a trip member 24 occupies a position in the same horizontal plane with its pin 29, and the rod be rotated in a clockwise direction, 29 will engage with 24 and rotate the pivot pin 22, thus releasing the set of wipers.

Only one trip lever 24 can be engaged at a time.

30. Sleeve near the lower end of rod 28.

31. Spring, one end secured to sleeve 30, which tends to rotate the rod 28 anti-clockwise to normal.

32. Fixed part to which the other end of spring is secured.

33. Another pin on sleeve 30 to be engaged by projection 34 on the pivoted armature 35 of the trip magnet 36.

37. Projection to limit the play of armature 35.

When the magnet 36 is energised, the extension 34 will engage with the pin 33 on the rod 28 to rotate it clockwise. On the de-energisation of 36, the rod will be returned to normal by the spring 31.

Means are provided for raising the wiper shaft at different speeds, and for returning them to normal by power drive.

38, 38′, 38″. Constantly rotating drive pulleys in alignment on one side of the elevating bars 39.

40, 40′, 40″. Idler pulleys, electromagnetically controlled, associated therewith, mounted in a removable frame on the opposite side of the bars 39. The several driving means are substantially alike; but the up-drive pulleys rotate at different speeds, and the down-drive pulley rotates in the reverse direction.

41. Arms carrying an idler pulley.

42. Bell-crank lever.

43, 44. Armature 43 of clutch magnet 44.

45. Common pivot pin for 42 and 43 carried by frame 75, 76.

46, 47. Bar 46 has upper end secured to spring 47.

48. Bolt to which the other end of spring 47 is attached.

49. Nut 48 is adjusted in 42 by this.

50. Adjusting screw threaded through armature to keep 42 in spaced relationship to 43.

51. Finger projecting from 46 which normally rests on projection 52 to limit the play of the armature.

When the clutch magnet 44 is energised, the idler pulley 40 will clamp the elevating bar between the idler and driving pulleys.

When the clutch magnet of the high speed pulley is energised, it is controlled indirectly by impulses created by the interruption of a circuit extending from earth, through plate 53, brush 54, conductor 55, brush 56 and interrupter 57. These impulses may be transmitted to the sending mechanism, not shown, which may act through a sequence switch, relay, or in any desired manner, to switch the supply of current at the desired moment, to the clutch magnet of the low speed pulley, or to cut it off altogether. The current to the clutch magnet of the low speed drive mechanism will be controlled during wiper selection over a similar

path, with the exception that brush 58 and interrupter 59 will be substituted, and during units selection the interrupter 60 will take the place of the interrupter 59.

61. Insulating plate in which the several brushes are rigidly secured to the yoke 62, which is fixed to the upper end of the shaft 1 (see Fig. 148).

The operation of the switch will be as follows :-

The low speed clutch will be operated to cause the elevation of the wiper shaft for wiper selection, the amount of travel, prior to the actuation of the trip rod 28, being measured by the pulsations produced by the interrupter 59. The high speed clutch will then be energised to trail the wipers of the released set over the terminals by tens, and the low speed clutch will be again energised to continue the travel by units to the desired terminal, the two latter operations being governed by the pulsations produced by the interrupters 57 and 60 respectively. When the desired terminals are reached, the upward travel of the shaft will be arrested by the de-energisation of the clutch magnet, and the shaft will be held in its elevated position by the engagement of the pawl 63 with the notches or openings 64 in the elevating bar. This pawl is mounted on a pin 65 extending through the plate 75 and 76, and is held in operative position by means of the spring 65'. At its lower end it carries a pin 66, adapted to be engaged by an upward extension 67 on the armature 43', upon the energisation of the down drive clutch magnet 44'. Thus, when release is desired the electro-magnet 44' will be energised, retracting the pawl 63, and simultaneously forcing the bar 39 into operative engagement with the down drive power pulley 38'.

As the shaft 1 approaches its normal position the brush 68 will engage the segment 69. This may be used to complete a circuit for a sequence switch, relay, or other device, whereby the circuit for the down drive magnet will be interrupted. Also, the restoring roller 25, on the trip lever 24, will be engaged by the cam member 70. This will rotate the wiper controlling member in a clockwise direction, whereby the wipers will be forced apart and separated from the stationary terminals, as shown in the upper half of Fig. 149.

The wiper shaft is hollow and has the circuit wires 71 enclosed therein. Branches from each of these wires are extended to the soldering terminals 17, of the corresponding wipers of the several sets on the shaft, thus connecting the corresponding wipers of all the sets in multiple. These wires terminate in the brushes 72, which engage the conducting strips 73, terminating in the conductors 74, whereby the telephone circuits may be readily extended to the brushes, and the corresponding brushes connected in multiple.

The driving mechanism parts are mounted in a separate frame as a unit, to allow of them being readily replaced by loosening a single screw.

75, 76. Frame of driving mechanism.

77, 78, 79. Extending arms, between which are clamped the core pieces of the magnets 36, 44, 44', 44''.

80, 81, 82. Show construction of bottom of frame.

83, 84. Bent portion of 75, 76, forming a tapering slot.

85. Lugs for plates 75, 76 at top.

86. Openings in bottom parts of frame 3 to admit 85.

87, 88. Spring in rear of frame to engage with angle bar 88 to prevent vibration

89. Supporting members.

90, 91, 92, 93. Members with lugs between which the armature 35 is mounted by means of pin 93.

94. The clutch frame is secured at its lower end by means of a single screw 99, passing through the tapered slot 84 into a frame part at 94.

95. Cylindrical projection on upper end of bar 39, fixed in lower end of hollow shaft 1 by means of the spring catch 96. Bar 39 can thus be readily removed.

The elevating bar 39 is numbered 10, 20, 30, etc., 10 notches apart so that the relative position of the wipers and the elevating bar may be readily known. As shown in Fig. 146 a set of wipers would be found on the thirty-first set of terminals of the section.

Section 68

BANK AND WIPER CONSTRUCTION OF PANEL SWITCH

The object aimed at is to arrange the terminals in the bank in the most compact manner, to eliminate wiring between the sets of terminals of adjacent switches, and to increase the adaptability of the switch. The design shown in Figs. 151—155 is to form a bank that will be suitable for either three or four wires per circuit, and to construct the wipers so that they will not make contact with adjacent terminals when passing up and down between the rows, and will make suitable contact when the wipers are tripped, with the respective terminals.

Fig. 151 is a front elevation of a portion of a bank panel with the contacting ends of the wipers outlined in position.

Fig. 152 shows four terminal strips, and the insulating sheets between the strips arranged in spaced relationship.

Fig. 153 is a plan view of a set of terminals, and a set of wipers for use therewith.

Fig. 154 is a side elevation of the last mentioned.

Fig. 155 is a cross section on the line 5—5. Fig. 151 shows the wipers tripped, and in transit from one set of terminals to another.

Schedule of parts as numbered in the illustrations.

1, 2, 3, 4, represent the terminal strips of a set for a line having the multipled contacts *a*, *b*, *c* and *d* respectively. The lugs or tabs on each metallic strip form multiple terminals of the same conductor on both sides of the panel, so that each line is accessible to wipers or brushes on each side. The terminals *a*, *b*, *c* and *d* constitute one set, and are arranged in superposed relation, but slightly staggered, so as to throw the contact edge of each to the left and right respectively of the unengaged portion of the other.

The terminals *b* and *d* are arranged on opposite sides of the pair of terminals *a* and *c*, and are spaced laterally therefrom in a manner to allow the passage of a brush between each and the adjacent terminals *a* and *c*.

5. The shaft which moves longitudinally.

6, 7, 8, 9. The wipers of a brush set. A set per bank is fitted to the shaft.

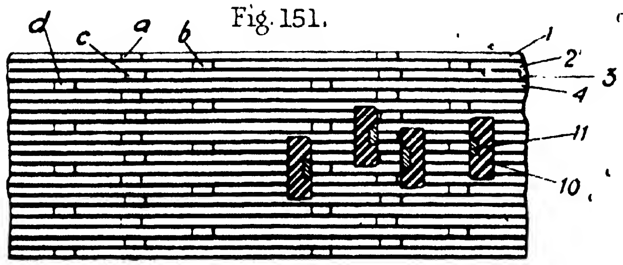
10. Blocks or shoes of insulating material fitted at the end of each wiper. In a recess is fitted the wiper part which makes contact with the terminal. The insulating shoes 10 are of such a size that they bridge the distance between adjacent terminals in the vertical rows.

11. The conducting strip or wiper.

For a three-terminal circuit the two inner wipers are connected together.

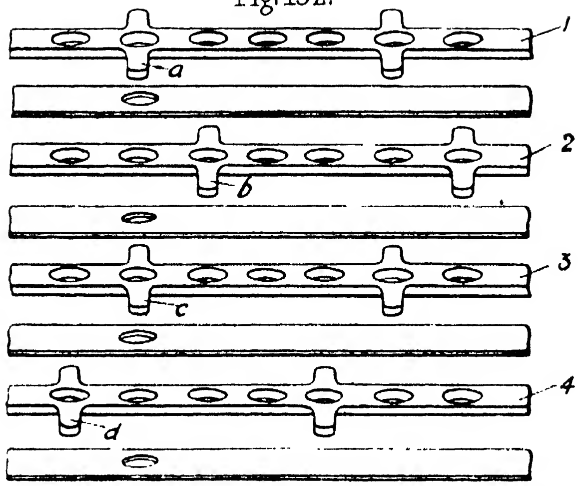
W. E. CO.'S PANEL SYSTEM. DETAIL OF BANKS AND BRUSHES.

Fig. 151.



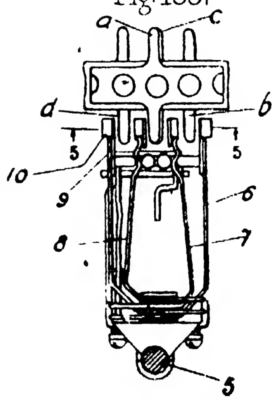
Elevation of Bank.

Fig. 152.



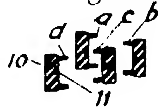
Terminal Strips and Insulation.

Fig. 153.



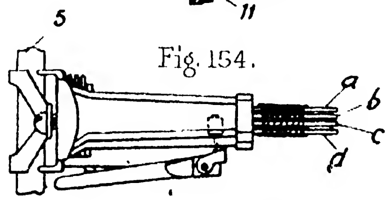
Brush Set - Plan.

Fig. 155.



Brush Set - Section.

Fig. 154.



Brush Set - Side View.

Section 69

SEQUENCE SWITCHES AS USED ON A PANEL SYSTEM

The function of the sequence switch (sometimes called a steering switch) is to automatically control a series of circuit changes, either of the same device, or of different devices in a definite and predetermined sequence.

As shown in Figs. 156—160, the form used in a panel system is of a horizontal type. A rotatable shaft is mounted in a suitable frame, and discs of insulating material are secured to the shaft. On each side of each insulating disc is mounted a conducting plate, each plate being cut away to provide a plurality of contact portions. The two plates associated with an insulated disc are usually electrically connected together by rivets. A plurality of springs or brushes is provided for co operation with each conducting disc, and it is obvious that by properly cutting away and arranging the plates or contact members on the insulating disc any two or more of the brushes may be electrically united at any stage of the rotation of the shaft. The switch is rotated in a manner similar to Fig. 93, in circuit Fig. 99.

The Positioning Device. This ensures that the switch will be accurately positioned in any one of its many positions. This device comprises a metal disc mounted on the rotating shaft. The disc is provided with a fluted or corrugated edge, there being one corrugation for each position of the switch. Adapted to engage these corrugations is a detent device, which comprises a roller mounted on a resilient support. This device may also act as an interrupter, and operate in connection with the power circuit of the motor magnet to maintain the motor magnet energised, and hence the switch in movement between positions, so as to prevent the switch from stopping between positions. This interrupter device is formed by cutting a plurality of radial slots in said disc, after which it is superimposed upon a disc of insulating material of smaller diameter. A suitable pair of brushes are provided, one of which rests upon the central part of the metal disc, and the other, during the rotation of the disc, alternately passes through the radial slots of the disc and rests on the insulating plate below, and upon the metal portions of the discs between the radial slots, thus interrupting the circuit.

Assembly.—The discs are provided with square central apertures which fit over a square section of the shaft, and interposed between each disc is a spacing sleeve of insulating material that insulates the discs from each other. As it is desirable, in some cases, to electrically connect the contact members carried by one disc to those carried by another, the spacing sleeve of insulating material may be surrounded by a sleeve of conducting material, which makes contact with the lower face of one disc and the upper face of another.

Fig. 156 is part section and part elevation.

Fig. 157 is a sectional view taken on the line 2 2 of Fig. 156.

Fig. 158 is a view showing the shaft with one of the insulating discs thereon, and the conducting plates arranged for engagement with each side of the disc.

Fig. 159 is a detached perspective view showing the mounting bracket for a brush set.

Fig. 160 is a perspective view of the positioning device detached.

The following is a schedule of parts corresponding to the symbols shown in the illustrations :—

1. The frame.
2. 3. Right-angularly extended portions on the frame.

W. E. CO.'S PANEL SYSTEM. DETAIL OF SEQUENCE SWITCH.

Sequence Switch, Part Section, Part Elev^{n}.

Fig. 156.

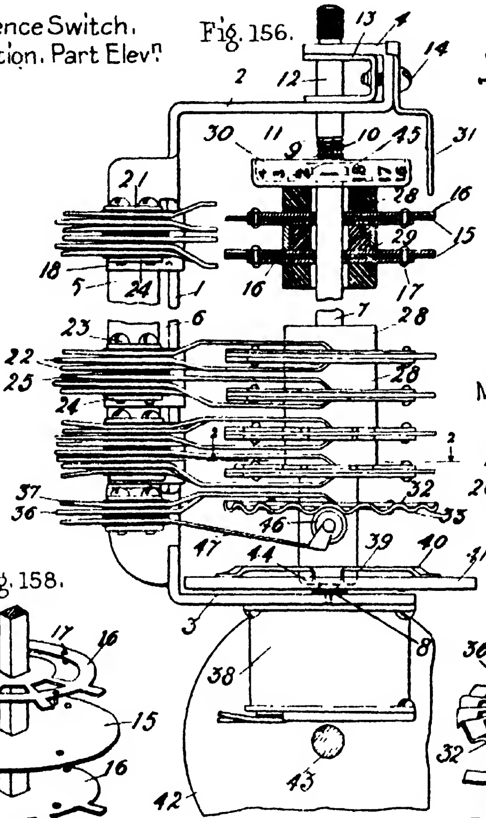


Fig. 159.

Mounting Bracket for Brush Set.

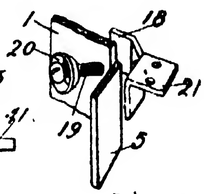
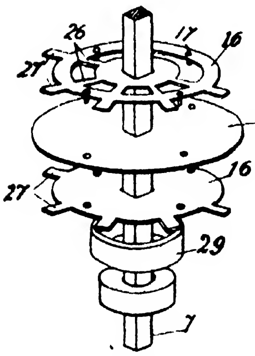
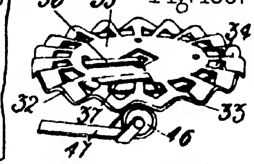


Fig. 158.



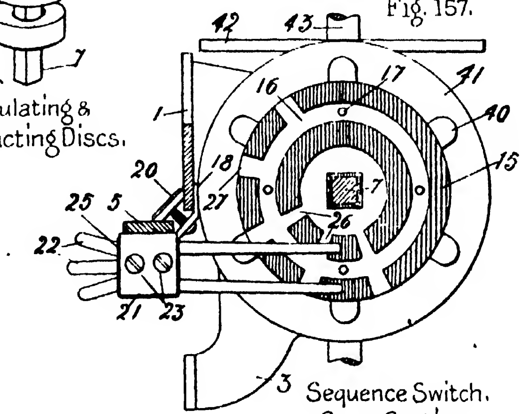
Insulating & Conducting Discs.

Fig. 160.



Positioning Device.

Fig. 157.



Sequence Switch, Cross Section.

4. Yoke-shaped member at one end of the arm 2.

5. Projecting shelf or ledge on the forward edge of 1.

6. The slot which separates the ledge 5 from the frame 1 (except at ends).

7. Square shaft mounted between members 2 and 3.

8. Bearing at one end of 7 in the member 3. The other end of this shaft is reduced and screw-threaded.

9. Screw-threaded portion of shaft.

10. Opening in 9 at the end to receive 11.

11, 12. Reduced portion 11 on the end of the pin 12. The pin 12 extends through openings in the frame 2 and the re-bent portion 4.

13, 14. Clamp and screw for above.

15. Discs of insulating material, non-rotatably mounted on the shaft.

16. Conducting disc or plate, one on each side of 15. These plates have segmental projections and curved cut out portions, whereby movable contacts are provided. It is to be understood that the various plates will in general differ from each other.

17. Rivets to secure the plates on the insulating disc and connect them together electrically.

18. A plurality of brackets are secured at the angle between 3 and 5.

19, 20. Screws which extend through the slot 6, which hold the bracket parts in engagement with the parts 1 and 5. The washer prevents the head of the screw from passing through the slot. This allows of the sets of brushes being readily adjusted.

21, 22, 23, 24. The portion of the bracket 18 which is in engagement with the ledge 5 is provided with the right-angularly extending portion 21, to which the springs or brushes 22 are secured by screws 23 and clamping plates 24.

25. Insulating separating pieces for springs. These springs are arranged at different levels. As shown, two brushes are provided for engagement with the contacts on each side of each disc 15, and all the contacts arranged on one side of the disc 15 are electrically united. Each bracket 18 supports two sets of brushes of four each, and thus carries the brushes for two adjacent discs 15. As shown in Fig. 157, the brushes which engage the contacts carried by the same metallic plate have their ends positioned at different radial distances from the shaft 7, so that one will engage one set of contacts, as 26, while the other will engage the outer series of contacts 27.

28. Spacing sleeves to separate the discs 15.

29. Conducting sleeves to unite plates of different discs.

30, 31. Disc with cylindrical rim having a scale. A pointer 31 secured to the yoke 4. These indicate the various positions which the switch assumes during one revolution.

32, 33. Disc with fluted edge of conducting material.

34. Cut-away portions near fluted edge.

35, 36. A brush 36 is arranged to co-operate with the imperforate portion 35.

37. A brush arranged to co-operate with the interruptions 34.

38. This construction may be used to complete the circuit for the magnet 38, by means of which the rotation of the switch shaft is controlled, while the switch is passing from one position of rest to another.

39, 40. Mounted adjacent to the positioning device, and at the end of the shaft, is a disc 39 of flexible metal having a plurality of substantially radially extending arms 40. 41. To the outer ends of this is secured an annular disc 41 of magnetic material.

42, 43. Friction disc rigidly fixed to the power shaft 43.

The controlling magnet 38 is located adjacent to the disc 41, and is so arranged that, upon its energisation, said disc will be attracted against the resiliency of its supporting arms 40 into forcible engagement with the rotating member 42, and the shaft 7 will thus be rotated.

44, 45. Nuts threaded on opposite ends of the shaft to clamp all parts together.

46, 47. Co-operating with the fluted edge 33 of the disc 32 is a roller 46 held in forcible engagement with said disc by the spring arm 47. This operates to bring the switch member to its exact position of rest, in case the energising current for the controlling magnet 38 should be cut off too soon, thus exactly positioning the contacts under the brushes. It also operates to prevent accidental displacement of the switch member. When it is desired that the switch member pass over certain positions, so that certain brushes may merely make passing engagement with their contacts or for other purposes, certain of the interruptions or perforations 34 may be omitted.

Section 70

PANEL SYSTEM CALLING LINE-FINDERS (Figs. 161-164)

In multiple brush panel switch units, any one of a group of lines may be seized by corresponding brushes, or wipers, of any one of a group of switches.

When a call is initiated on one of the lines terminating at a group of switches, a tripping device, common to the group, will be actuated, and is arranged to release, or render active, the wipers normally inactive which have access to the calling line terminals of any of said switches which are in the normal position. Only one tripping device can be in the actuated position at a time. The tripping devices are common to all the switches of a group, one tripping device being provided for all the brush sets having access to the same section of the panel bank. The tripping device for releasing the desired set of brushes is operated prior to the actuation of the switch. This allows selection to take place rapidly without preliminary brush selection.

Fig. 161 is a side elevation of one form of a 500-line call-finder panel switch with parts broken away, having a common trip rod.

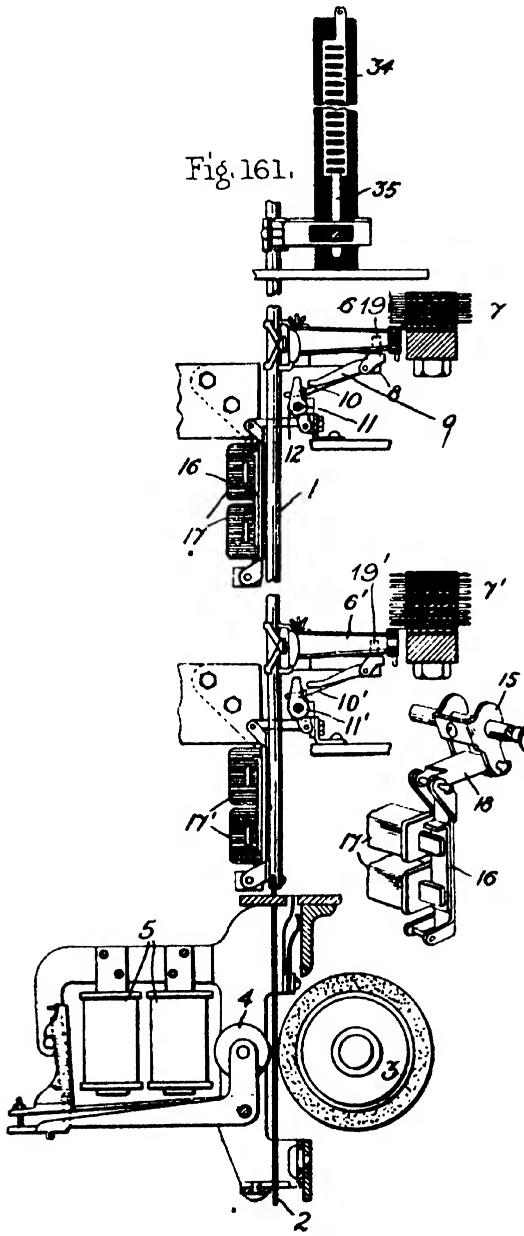
Fig 162 is a perspective view of a portion of the trip rod, together with the trip and restoring levers of a pair of brush, or wiper, controlling devices.

The following is a schedule of the various parts with reference to the symbols on the drawings.

1. The finder switch shaft, which moves longitudinally.
2. An extension of 1, by which it is raised and lowered.
3. A constantly rotating power member.
4. Idler pulley, between which and the rotating member 3 the extension 2 is clamped or gripped.
5. Clutch magnet, which operates the pulley 4.

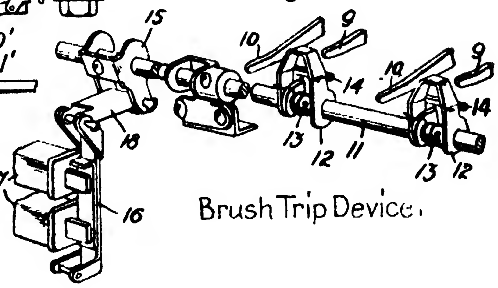
W. E. CO.'S PANEL SYSTEM. ONE FORM OF CALL FINDER.

Fig. 161.



Call Finder Panel Switch – Side View.

Fig. 162.



Brush Trip Device.

6. Wiper, or brush, sets, of which there are usually five, secured to the shaft 1. Corresponding brushes are multipled together.

7. A section of a terminal bank, with which a set of wipers is adapted to traverse and make contact.

8. A brush controlling device, by means of which the wipers are prevented from making contact with the terminals normally. When this is rotated, the brushes make contact with the terminals by the resiliency of the metal of the wipers.

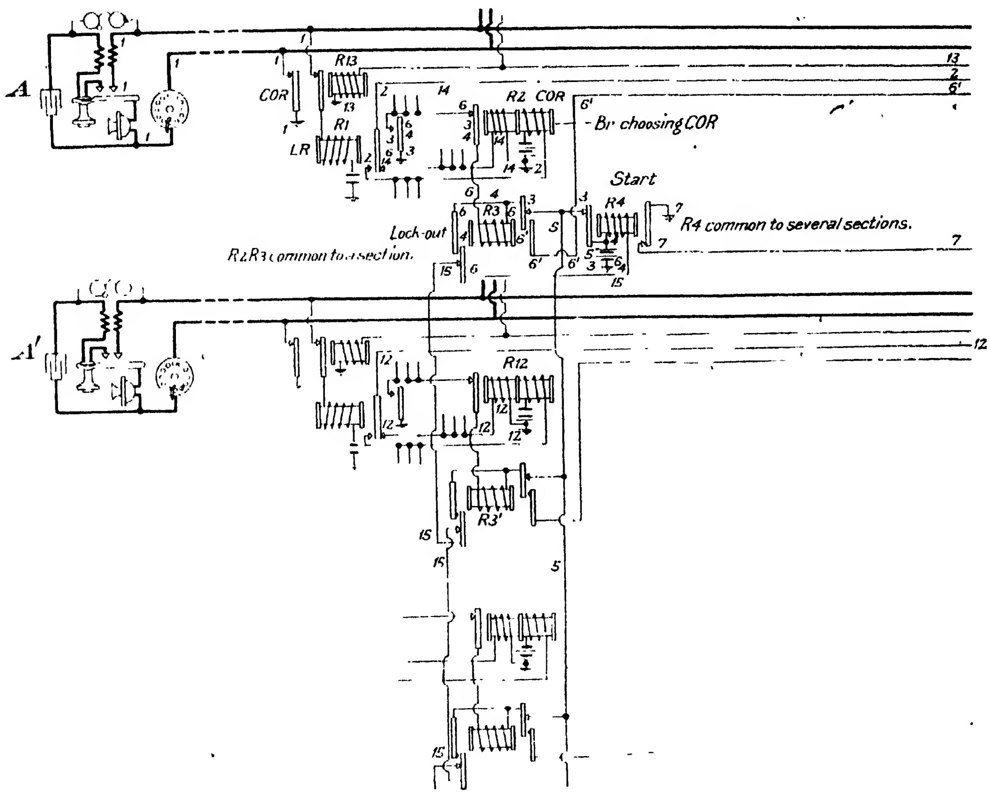


Fig. 163.—Subscribers' Lines on a Panel System Finder Switch (W. E. Co.).

9. The trip lever, one being secured to each controller 8.

10. The restoring lever.

11. Trip rods. Extending transversely to the shafts 1 of a group of switches are a plurality of rotatably mounted trip rods, one for the corresponding sets of brushes of a group of switches. These are positioned just below the restoring levers 10 of the brush sets when they are in their normal position.

12. Yokes or U-shaped members, rotatably secured to the rods 11, one being provided for, and in operative relation to, each of the trip levers 9 adjacent thereto.

13. Springs, which have one end secured to the rod 11 and the other end to one of the yokes, and tend to force the yokes in a clock-wise direction.

14. Stops on the rod which limit the travel of the yokes.

15. A bracket member fixed to each of the rods 11, near one end.

16. Armature to which the bracket member is secured.

17. Trip magnet.

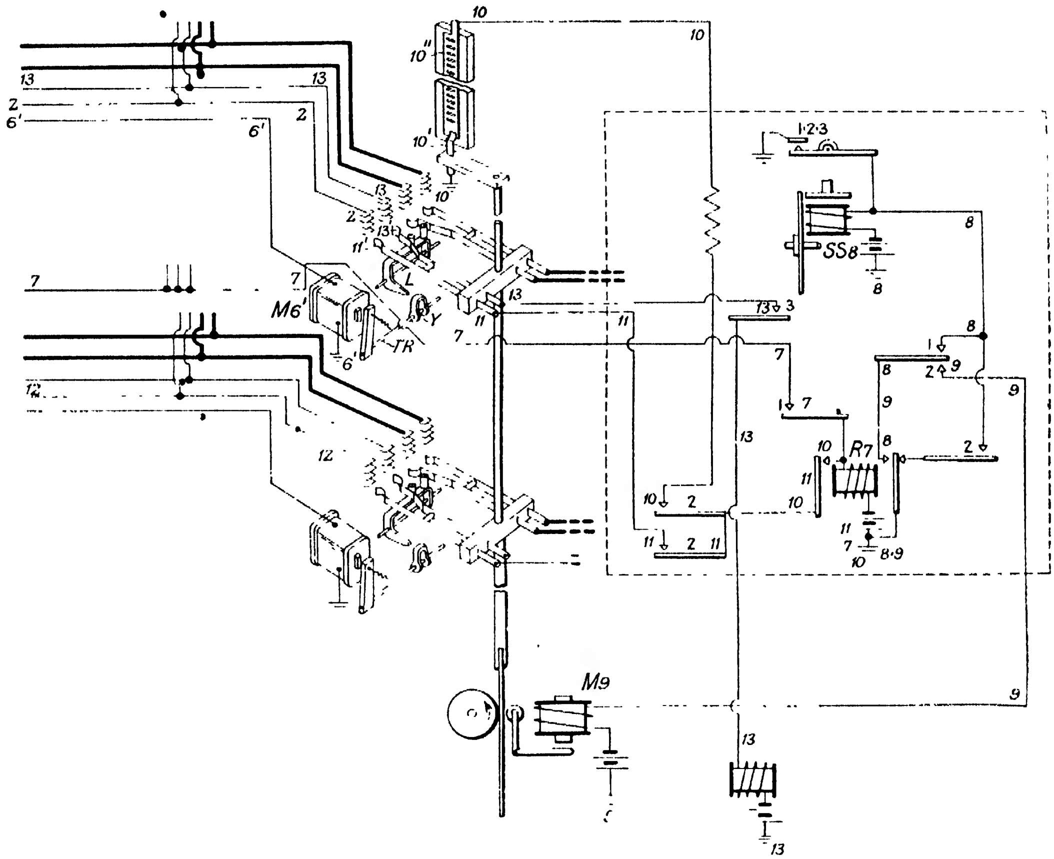


FIG. 164.—SUBSCRIBERS' LINES ON A PANEL SYSTEM FINDER SWITCH (W. E. CO.). SEQUENCE SWITCH CONTROLLING CIRCUIT.

18. A link connecting the bracket member to the armature.

Upon the energisation of the magnet 17 and the attraction of its armature 16, a corresponding rod 11 will be caused to rotate in a clock-wise direction. This will place the yokes 12 above, or in operative relation to, the trip levers 9 of all the switches of the group which are then in normal position. If, now, one of the shafts be raised, the trip levers and the restoring levers are prevented by the yokes from moving upwards also, in the initial movement of the switch. This will cause the levers to rotate about their supporting pivots, thus moving the spacing member 19 from between the inner wipers of the operated switch.

When the operated switch returns to normal the downward movement of the brush carriages, to which the restoring levers are pivoted, causes the levers to engage the trip rod and, thereupon, the restoring of the spacing members 19 into their normal position, between the inner wipers, thus removing the wipers from contact with the terminals.

Figs. 163, 164 show suitable circuits for controlling such a switch. The circuits are numbered in the order of operation, and are as follows :—

1. When the receiver is lifted line relay R′ energises.

2. Battery is connected through the brush-choosing cut-off relay R2, which is connected to the test terminal of the call-finder.

3. The lock-out relay R3 energises.

4. Start relay R4 energises.

Relay R4 is common to all the lines terminating in the several sections of the panel bank of a group of switches. R2 and R3 are common to all the lines terminated in a section of the panel board.

5. This circuit is opened whilst one subscriber is calling, to prevent other calls interfering at that instant, battery then being cut off the common circuit.

6. Holding circuit for relays R3 and R4.

6′. Trip magnet M6′ energises, in parallel with R3 and R4, and rotates the trip rod TR, so as to place the yoke Y over the lever L of such of the switches as are in normal position on that level.

The finder switch next to be employed is preselected and only the sequence switch of this preselected finder is in position 1.

7. Relay R4 energising completes the circuit for R7, which energises.

8. Sequence switch SS8 energises and moves to position 2.

9. Up-drive clutch magnet M9 energises to lift the shaft. As it leaves the normal position the wiper set adapted to traverse the section of the panel in which the calling line terminates is tripped by the yoke Y over the lever L.

10. Holding circuit for R7 over interrupter segment. R7 is locked over the brush 10′ and segment 10″, except when the brush 10′ is on an insulated segment (when it de-energises), which occurs when the wipers of the switch are centrally positioned on a set of terminals.

11. Battery connected through relay R7 to the test wiper.

The test terminals of all non-seeking lines are connected to earth.

12. When the test wiper touches the first idle line, relay R12 energises over circuit 12 (12 being common to a section), and breaks the corresponding circuit 6.

Relay R7 will be maintained energised, alternately through brush 10′ and through test wiper 11′, until the calling line is found.

When the calling line is found, and the wipers centred, R2 and R7, which are connected to the same pole of the battery, de-energise.

If, in the meantime, another call has been initiated in the A line group, the circuit for R3 will be again completed and another line-finder can operate.

Circuit 8 is again completed and SS8 moves to position 3.

13. The cut-off relay R13 energises to open circuit 1, and R′ de energises.

14. Wire 2 is extended through the left-hand winding of R2 to earth.

Simultaneous Calling.—If subscribers A and A′ call at the same time, relays R3 and R3′ will both energise (as in circuit 3). R3 will open circuit 15, and thereby cuts battery

from R3′, so that only the trip magnet R6′ can energise. Relay R4 is then energised and cuts battery from circuit 5, so that R3′ de-energises. As soon as the switch searching for the A subscriber reaches the first terminal, R3 and R4 are released and the selection of A′ will take place.

Section 71

MESSAGE REGISTERING, OR METERING, IN A PANEL SYSTEM

The important feature of the circuits, Figs. 165—168, is the provision of a controller for controlling the operation of the register or meter in an automatic system, which controller is automatically associated with any one of a group of connection circuits, used in establishing the connection, to selectively control the operation of the calling subscriber's meter. An idle one of a plurality of controllers is automatically associated with the connecting circuit used. The circuits illustrate how metering is effected on direct exchange lines, P.B.X. exchange lines, and how the meter is prevented from operating on non pay lines.

Figs. 165 167 show a circuit, established through a large system, between stations A and B. Fig. 168 shows the message register controlling apparatus, which is common to the connection circuits, sometimes called cord circuits.

The circuit is assumed to have been extended from A to B in any known manner. For example, the line may have been extended to the call-finder, in the manner shown in Fig. 163, by group selectors of the type shown in Fig. 143, and to final switches of a similar type, the connection being built up step by step by registers and revertive control as shown in Figs. 118 to 124.

The circuits are numbered as follows :

0. Line circuit from station A to repeater, in which relay R0 is energised.

1. Line circuit from called station B to repeater, in which R′ is energised.

2. R0 energised, completes a circuit for relay R2, which energises

3. Third conductor circuit of a direct line, completed through R3 and meter M13, in parallel.

3′. Third conductor circuit of a P.B.X. line, completed through R3′ and meter M21, in parallel.

4. Sequence switch SS4 in position 13, where it will remain until the calling receiver is replaced.

5. R5 energises over R′ contact.

6. R5 locking circuit.

7. When the calling receiver is replaced relay R0 de energises, then R2, and SS4 steps to position 14.

8. Relay R8 (Fig. 168), of a message register controller allotter (in dotted rectangle), energises over contact of R5 (Fig. 166).

9. Magnet M9 of an idle preselected message register controller cord finder energises, when the brushes are rotated and engage the contacts associated with the trunk, through which the connection was established.

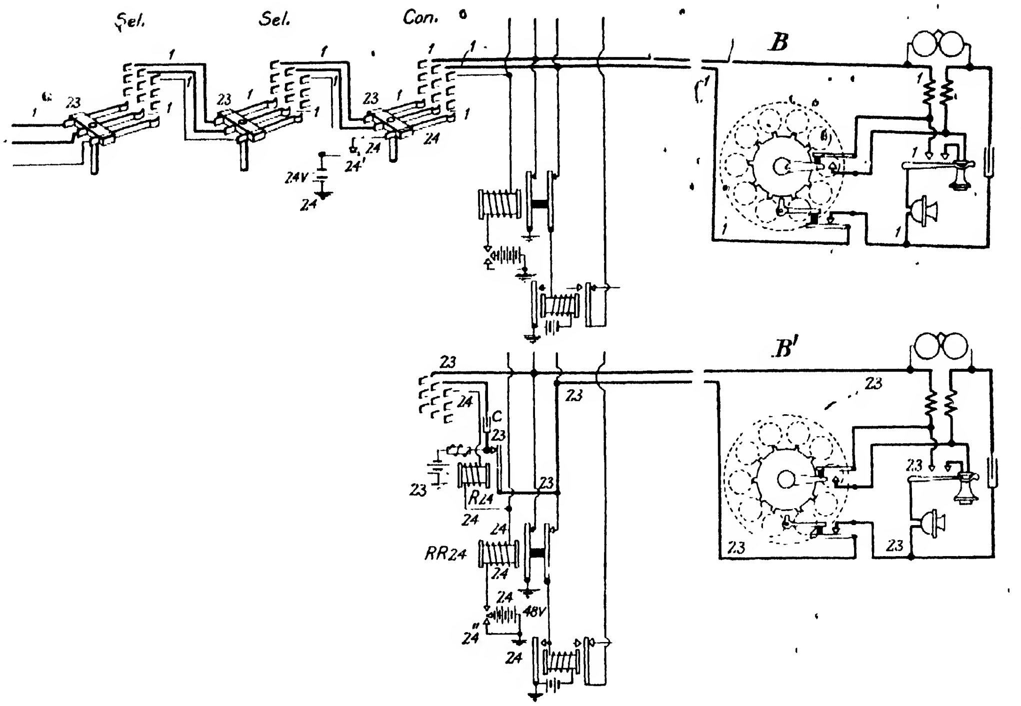


FIG. 167. A METERING CIRCUIT ON A PANEL SYSTEM (W. E. CO.) SELECTOR TO CONNECTOR.

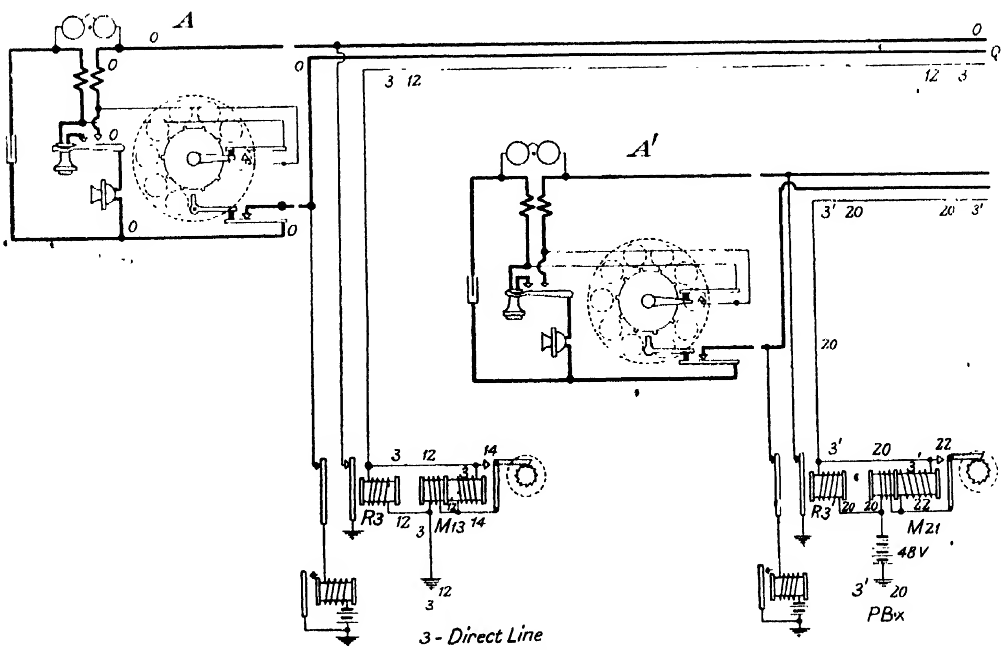


FIG 165.—A METERING CIRCUIT ON A PANEL SYSTEM (W. E CO). SUBSCRIBERS' LINES.

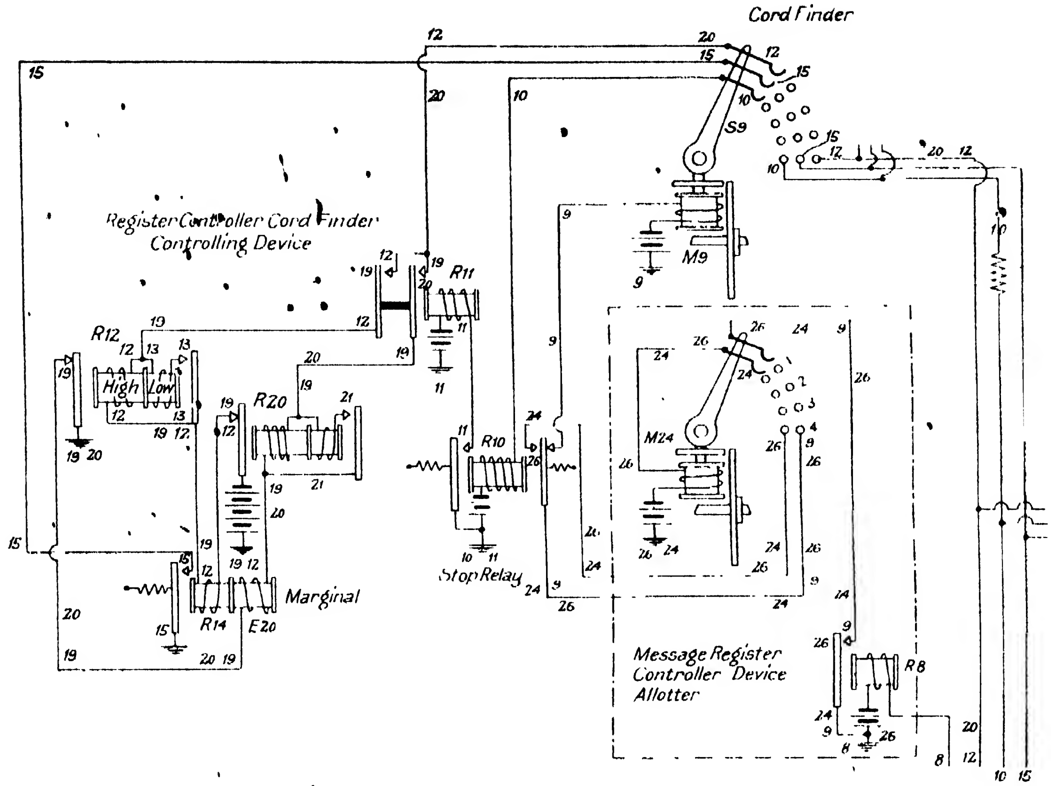


Fig. 168.—W. E. Co.'s Metering Controller and Allotter Circuit.

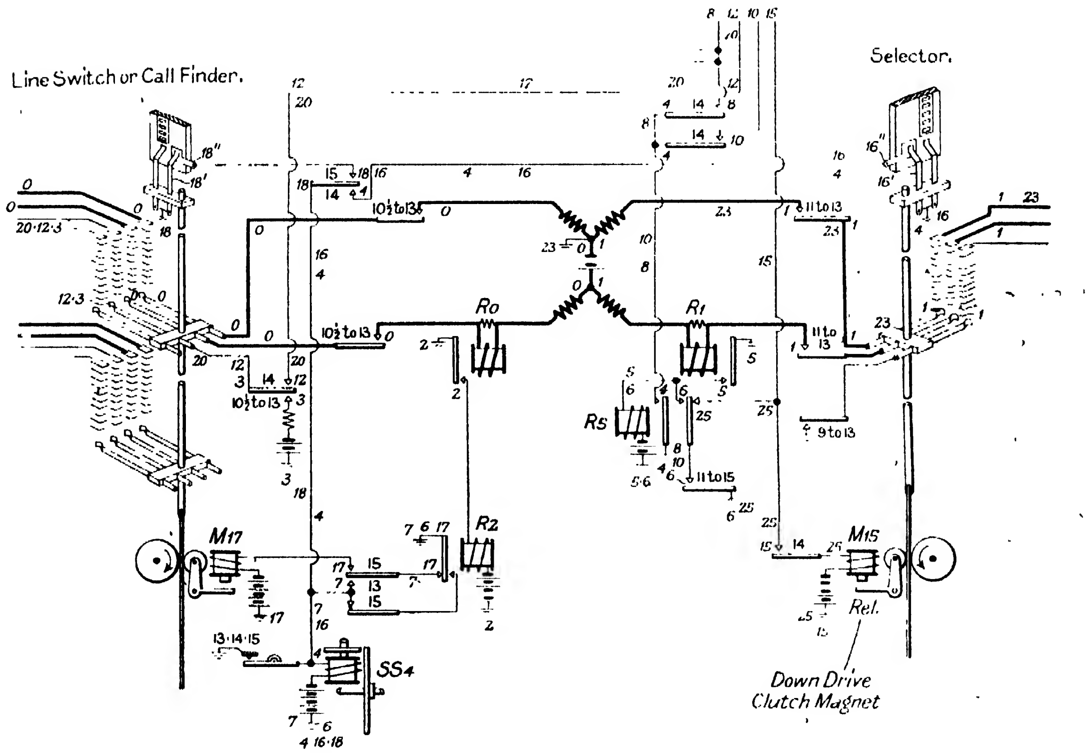


Fig. 166.—A Metering Circuit on a Panel System (W. E. Co.). Call Finder to Selector. A.T.S.

10. R10 of MRC energises (over contact of R5) and opens circuit 9, so that M9 de-energises and stops the brushes.

11. Relay R11 energises.

12. R12 energises over R3 (Fig. 165), and meter M13 in parallel.

13. Low resistance shunt winding of R12, to increase the current in the circuit so that M13 energises.

14. M13 operating brings in the low resistance parallel winding to still further increase the current in the circuit, so that the marginal relay R14 energises.

15. The down drive clutch magnet M15 energises to restore the switch to normal.

16. As the switch approaches normal, the commutator brush 16′ engages the segment 16″, and SS4 energises and moves to position 15.

17. The down drive clutch magnet M17 of the call finder restores the shaft to normal.

18. As the shaft approaches normal, the brush 18′ makes contact with the segment 18″, and SS4 steps to normal or subnormal position as desired.

19. At the time R11 energised in circuit 11, R24 did not energise owing to the resistance in the circuit.

We will now assume that the calling line is in a P.B.X. group as shown at A′ when the wire 3′ is connected through relay R3′ and meter M21 in parallel to 48-volt battery and earth.

20. The current in this circuit is assisted by the current flowing in circuit 19, and R20 now energises and cuts out of the circuit the resistance of relay R12 winding.

21. Low resistance shunt winding of R20 to increase the current, so that the meter M21 energises and registers.

22. M21 energising, brings in the shunt winding to increase the current still more, so that the marginal relay R14 energises to complete circuit 15, when the selector and call finder are released as before.

Circuits for a non-pay station are shown at B′.

23. The circuit of line B′ from instrument to repeater. The condenser *c*, at B′, is then in series with the connection circuit relay R′, so that R′ does not energise.

24. The circuit for R24 depends on whether B′ is a direct line or a line in a P.B.X. group. As the battery at the sequence switch contact 24′ is of 24 volts, and that associated with relay RR24 is 48 volts, R24 and RR24 will be energised whether connected to battery or to earth.

As relay R′ does not energise on a non-pay call, the circuit of R5 is not completed. R5 therefore remains de-energised, and circuits 8 and 10 are not completed.

Now when the caller replaces the receiver, SS4 moves to position 14 as before, but the register controller will not be energised.

25. The down-drive clutch magnet M15 is energised and the release is as before described.

The message register controller shown at Fig. 168. A plurality of such controllers would be provided, the allotter M24 functioning at all times when at rest to maintain an operative circuit direct to an idle controlling device. Assume now that the brushes of the allotter M24 are on contacts individual to an idle register controller, and that a successful call is disestablished. This will cause the energisation of relay R8, which will complete a circuit for the motor magnet M9 of the cord finder switch arm S9 as before described. When the cord finder engages, the contacts of the desired trunk line relay R10 will be energised.

26. The allotter moves from set to set of the contacts individual to the register controller. The allotter M24 will continue to rotate until its brushes engage the contacts to an idle register controller. As the contacts of the second register controller may be engaged by the allotter, before the trunk sequence switch SS4 has moved out of position 14, a second cord finder, corresponding to S9, may be started into operation, but on account of the marginal character of the stop relays R10, the relay R10 of the second cord finder will not operate when the brushes of its cord finder S9 engage the contacts individual to the trunk through which the connection is being disestablished.

Section 72

THE WESTERN ELECTRIC CO.'S SIMPLIFIED METHOD OF CHANGING-OVER FROM A MANUAL TO AN AUTOMATIC SYSTEM

In an existing large manual system it may be desired to introduce automatic working, but the huge cost may prevent the conversion being carried out as expeditiously as efficiency demands. Again, much of the manual plant may be comparatively new, and it may therefore be considered advisable to delay the conversion of such offices until the less efficient plant has been replaced. The conversion may therefore be spread over a number of years.

A feature that is considered objectionable by the subscribers is the change of directory numbers which usually follows the introduction of a change of working or concentration of plant and the like.

The W. E. Co.'s new arrangement is designed to simplify such a change over to full automatic working without change in the subscribers' numbers.

The system to be described supposes a manual system capable of extension to 700,000 direct exchange lines which it is proposed gradually to replace by automatic working. This total may be sub-divided into 70 offices, each of 10,000 lines, or a greater number of offices, a considerable proportion of which are of smaller capacity. Each office is numbered from 0 upwards, the largest offices numbering to 9,999. The maximum number of digits in the existing numbers is, therefore, usually four, prefixed by the name of the office, as for example, Gerrard 4,444. As the numbers begin with 0, there will also be Gerrard 4, Gerrard 44, and Gerrard 444.

In a full automatic system the number of digits is usually uniform in each subscriber's designation number.

The new arrangement provides for calling numbers with varying series of digits, as in the examples given above.

The arrangement assumes that the necessary selectors and connectors are provided in each manual office so that the subscribers can be called automatically from any automatic office, or that the incoming junctions on manual positions are equipped with their device for displaying on lamps the number of the desired connection, the lamps, corresponding to the digits dialled by subscribers on the automatic exchange, being illuminated (as described in Section 58).

The dials carry letters and figures as shown in Fig. 139.

The capacity of 700,000 is arrived at because the digits above seven are required for the working of the system. The initial digit 8 is associated with, for example, the letter H, 9 with K, and 0 with L. Figures 8, 9 or 0 cannot, therefore, be the first digit of a subscriber's number if the whole were expressed in figures.

The Gerrard office may be allotted the numbers 20,0000—20,9999, the digits 20 being the office prefix, corresponding to the name Gerrard. To facilitate calling and memorising, the number prefix 20 is preferably replaced by letters.

In a full automatic number scheme it would be necessary to dial, *e.g.*, BL0004 for Gerrard 4, BL0044 for Gerrard 44, BL0444 for Gerrard 444, and BL4444 for Gerrard 4444. It is desirable to eliminate the valueless ciphers, and this is accomplished by introducing an additional letter prefix, and the arrangement then becomes: LBL4 for Gerrard 4, KBL44 for Gerrard 44, HBL444 for Gerrard 444, and BL4444 for Gerrard 4444.

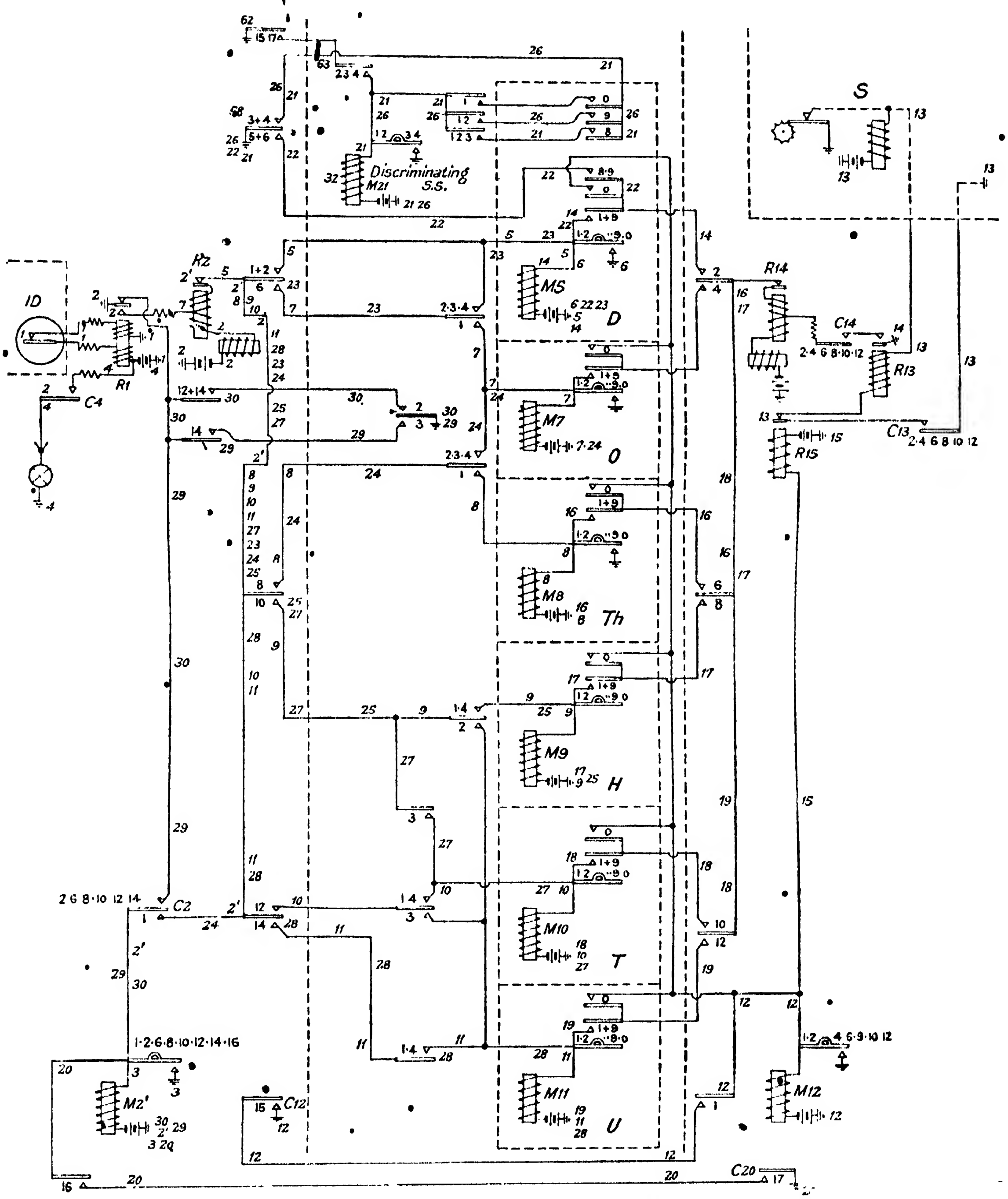


FIG. 169.—W. E. CO.'S REGISTER CIRCUIT, WHEN CHANGING FROM MANUAL TO AUTOMATIC WORKING.

When the first letter dialled is L, the numerical suffix has but one digit, but the device is so controlled as to bring about the selection which would have been produced by the eliminated ciphers. Similarly, when the first letter dialled is K, the number has two digits, and when the first letter dialled is H, the number has three digits.

The following is suggested as a method of directory listing for joint manual and automatic working: —Gerrard (LBL)4, Gerrard (KBL)44, Gerrard (HBL)444, and Gerrard (BL)4444.

After the whole system is converted to automatic working, the name would be omitted, and automatic practice reverted to.

It is preferred that the transmission of impulses for the first digit H, K or L should set the first register to a position corresponding to the number of impulses transmitted. The register, by moving to that position, causes a discriminating sequence switch to be moved to a particular position depending upon the position to which the register was set, in a manner to be described.

A sequence switch controls the connection between the registers and the line relay receiving the impulses, so that certain such registers are passed over, the number thus passed over depending on the value of the prefix H, K, or L.

In the diagram (Fig. 169), *ID* represents an impulse dial at a subscriber's office. *S* represents, diagrammatically a selector or group switch. *D* is a register-controller controlling access to a *district* of, say, 100,000 lines. O is a register controlling an *office* in such a district. *Th* controls access to a group of 1,000 lines. *H* controls access to a group of 100 lines in the above group. *T* controls access to a sub-group of 10 in the above 100. *U* controls access to a line in the sub-group of 10. M21 is the special *discriminating* sequence switch which determines the registers that are to be ineffective.

The impulse dial *ID* sends impulses equal in value to the digit (10 impulses being sent for 0).

The group selectors are operated on the *revertive control* system.

It will be readily understood that the arrangement may be applied to systems greater or smaller than 700,000 lines.

The circuits (Fig. 169) are numbered as follows:—

Calling a Number with Full Numerical Suffix, as Gerrard (BL)4444.—

1. When the receiver is lifted, relay R′ energises.

2. Current is through both windings of R2 (differentially wound) which does not energise.

2′. Sequence switch M2′ moves to position 2.

3. SS M2′ local control circuit. Contact C2 opened. Current over circuit 2 only, and R2 energises.

4. Dialling tone given to caller.

5. M5, 100,000 district register D, energises and moves to position 1, and stops there till the caller dials.

6. M5 local control circuit. Upper winding of R2 is also short-circuited.

The subscriber calls B (or 2).

Relay R′ de-energises during the first short interruption. Circuit 2 is open, and R2 de-energises. The subsequent energisation of R′ closes circuit 5, and register D moves to position 2. R2 is again short-circuited in circuit 6 so that it energises in position 2.

The last, or longer, interruption of the digit (B or 2) de-energises R2, and is also of such duration as to drive SS M2′ from the second to the sixth position.

The second digit L or 0 is dialled. This calls into the ten thousands or office register O.

7. The operation is as before, M7 being set over circuit 7 and SS M2′ being moved into its position 8.

8. *When the third digit 4 is called,* the thousands register Th is set, in position 8 of the sequence switch M2′.

9. *When the fourth digit 4 is called,* the hundreds register H is set in position 10 of SS M2′.

10. *When the fifth digit 4 is called,* the tens register T is set in position 12 of SS M2′.

11. *When the sixth digit 4 is called,* the units register U is set in position 14 of SS M2′.

12. When SS M2′ moved from position 14, on the completion of the registration of the units digit, it closed the sequence switch contact C12, and a circuit was completed for the outgoing sequence switch M12 in its normal position (position 1), thereby initiating the controlling operations (as described in Sections 43 and 54).

13. In SS M12 position 2, the fundamental circuit 13 to the selector switch is adapted to perform the first selection operation. The circuit is closed at C13. R13 energises and de-energises intermittently (C′14 being closed). R14 (outgoing differential relay) operates as elsewhere described until the register D is restored to normal.

15. Register D is restored to normal by the cut-off relay R15, and SS M12 operates to terminate the selection.

The second selection-control operation follows, in the fourth position of SS M12. This operation is terminated, consequent upon the first revertive impulse received from the selector switch, the register O being in position 0.

The third or thousands selection control operation takes place, under the control of the thousands register Th, in position 6 of SS M12.

16. Register M8 (Th) control circuit.

The hundreds selection control operation is under the control of the register H, in position 8 of SS M12.

17. Register M8 (H) control circuit.

The tens selection control operation is under the control of the register T, in position 10 of SS M12.

18. Register M10 (T) control circuit.

The units selection control operation is under control of the register U, in position 12 of the SS M12.

19. Register M11 (U) control circuit.

20. The sequence switch M12, in returning to normal from position 12, closes contact C20, to initiate the movement of SS M2′ to normal.

The entire equipment is again at normal.

Calling a Number with a Three-digit Suffix, as Gerrard (HBL) 444. The register D must be set in position 2, register O in position 0, register Th in position 0, and H, T and U in position 4.

Register Th is unaffected and the other registers are operated as before.

The first register controller is, as a preliminary, operated to cause the discriminating sequence switch M21 to take an appropriate position for omitting the register Th, or the registers Th and O, or the registers Th, H and T, as the case may require, from the setting operations controlled by the line relay R′.

The first digit to be transmitted is H (or 8), and the register D is set to position 8

21. As the SS M2′ passes from position 2 to 6 it closes, in positions 3 and 4, a circuit for M21, which energises and advances to position 4.

22. In positions 5 and 6 of SS M2′ register D is restored to normal, or position 0. The register D is now ready to register the next digit transmitted, which is the first actual digit of the numerical designation of the desired line.

23. Control circuit of register D.

24. After the register D has been set, the register O is set as before, with SS M2′ in position 8.

When the register O is set, and the discriminating SS M21 in position 4, there is no circuit for the register Th.

25. Control circuit of register H.

Registers T and U are set as before.

The registers are thus set to call the number 200,444 (Gerrard 444).

The selection-control operations are as before described.

Calling a Number with a Two-digit Suffix, as Gerrard (KBL) 44.—The registers Th and H are unaffected in the setting operations.

The transmission of the preliminary digit K (or 9) places the register D in position 9.

26. Consequently the discriminating SS M21 is moved to its position 3, when SS M2′ passes through positions 3 and 4.

Register D is restored to normal, over circuit 22, when SS M2′ passes positions 5 and 6.

Registers D and O are then set, when SS M2′ passes positions 6 and 8 respectively, by the next two sets of impulses transmitted.

With SS M21 in position 3 no circuits are closed for the registers Th and H.

27. Register T is energised by the tens impulses.

28. Register U is energised by impulses in position 12 of M2′.

29. With SS M21 in position 3, SS M2′ is driven through its position 14.

The number 200,044 (Gerrard 44) has been set.

Calling a Number with a Single-Digit Suffix, as Gerrard (LBL) 4.—The registers Th, H and T are not set, in a manner as previously described. The preliminary digit L (or 0) sets the register D in its zero position and causes the discriminating SS M21 to be set in position 2.

The effective setting of register D takes place in accordance with the first actual digit of the designation of the desired number, in position 6 of the SS M2′, as before described.

Register O is set for the next digit, in position 8 of SS M2′, as before.

In position 10 of SS M2′ register U is set for the single digit (4).

There are no circuits for registers Th, H or T in position 2 of the discriminating SS M21.

The number 200,004 (Gerrard 4) has been set.

30. SS M2′ will pass through positions 12 and 14.

In the automatic system proposed for London and New York a three-letter prefix with a four-figure suffix is contemplated. The prefix consists of the first three letters of the name of a manual office and the dialling of these routes the call to that particular centre; and the dialling of the four-figure suffix connects with the particular line in the particular office. See Section 65.

Section 73

THE LORIMER AUTOMATIC TELEPHONE SYSTEM

Each section of this automatic system constitutes by itself a complete unit that can be used as an exchange for 100 subscribers, or, in connection with other sections, may be used for an exchange of as many hundreds of sub-stations as there are sections. For an exchange of 1,000 sub-stations no addition to each of the 10-unit sections employed would be required. When the exchange is extended to a second thousand, it is only necessary to employ upon each sub-division of each section an additional *interconnector*, a duplicate of the interconnector which would be employed with the exchange when organised to accommodate 100 subscribers, or any greater number up to 999.

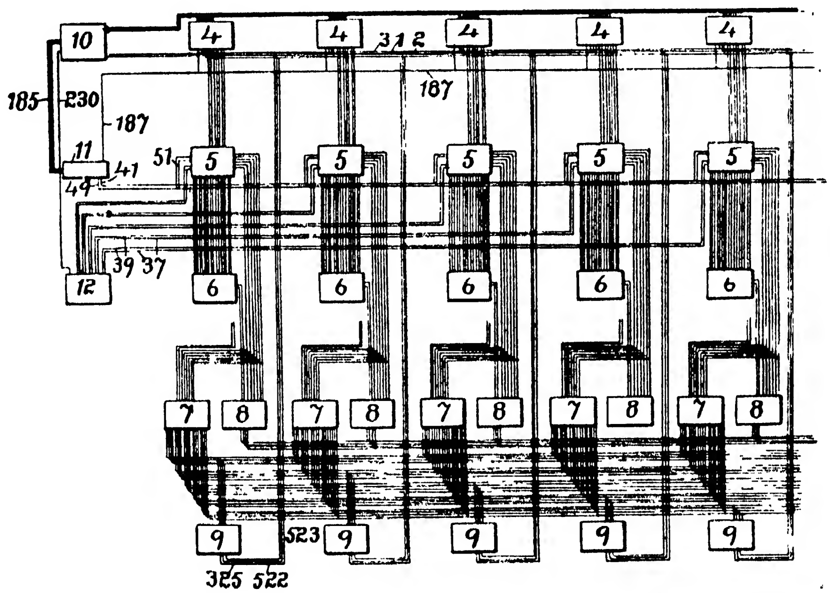


FIG. 170.—SKELETON DIAGRAM OF ONE SECTION OF A LORIMER EXCHANGE, SHOWING ONLY FIVE OF THE TEN DIVISIONS OF CONNECTING APPARATUS.

In the skeleton diagram, Fig. 170, the principal parts for five divisions of one section of 10 are shown. The parts are thus designated. 4 is the primary connector; 5 is the rotary switch; 6 is the signal transmitter controller; 7 and 8 the two interconnectors respectively for the first and second thousands of the exchange; 9 the secondary connector; 10 the decimal indicator; 11 the decimal register controller, and 12 the division starter. Fig. 171 shows a general view of the apparatus as installed at Hereford.

Before describing in detail the several parts of a division, the construction of a cylinder switch and clutch, and a register switch suitable for various parts, will be first described.

Cylinder Switch.—Referring to Figs. 172 and 173, the fixed contacts 60 are pieces of wire or sheet metal secured in plaster of Paris or other insulating material. In the diagrams the contact ends of these pieces are shown by circles. Their inner ends project for engagement by the switch brushes, while their outer ends are left free for the attachment of wires or conductors. The cylinder shown has 12 longitudinal rows of contacts 60, each row or ring containing 44 contacts, or four quadrants of 11 contacts each. Four corresponding sets of brushes, of which there are 12 in each vertical row, engage with the inner ends of the contacts and are carried by shaft 62 driven by gear-wheel 63

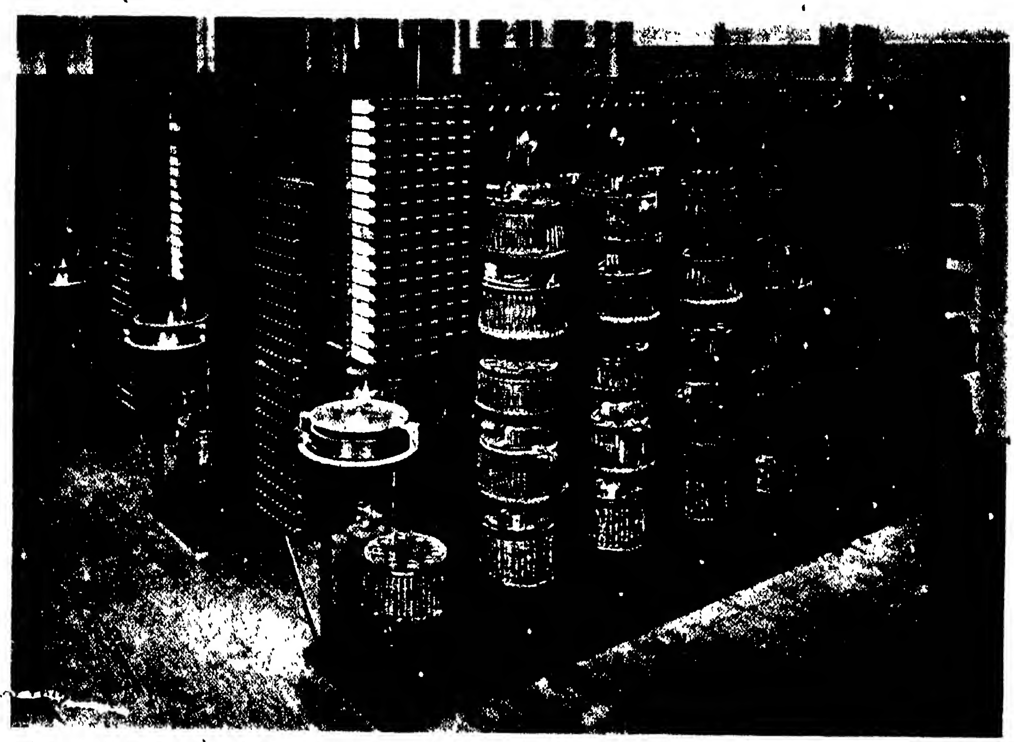
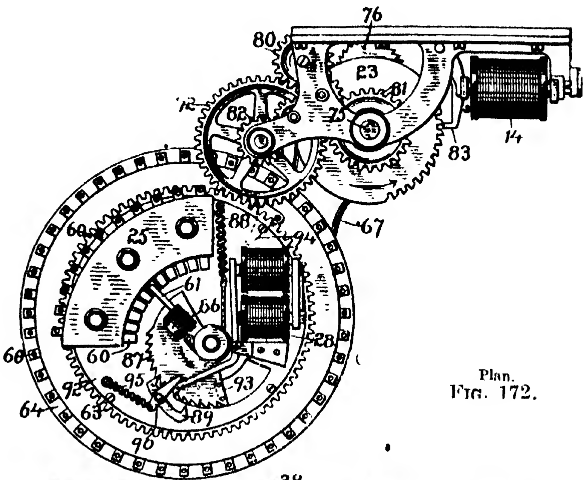


FIG. 171. GENERAL VIEW OF A LORIMER EXCHANGE INSTALLED AT HEREFORD.
(From P.O.I.E.E. Journal, by permission.)

The cylinder 24 is fastened between two plates 64. The lower one is secured to a plate 65, carrying a bearing for the shaft 62, and provided with a depending pivot 66, that enters a socket in the bracket 67, secured to the frame of the apparatus. This construction permits the cylinder to be swung away from its driving gear, and allows ready access to the outer ends of the contact plates, or points, around its whole periphery. Each brush 61 consists, preferably, of two springs turned up at their forward edges to permit them to slide readily into contact with the ends of the plates 60, and grasp said ends between them. The brushes 61 (Fig. 174) are set in slots cut in a block 67, of vulcanite or other insulating material, and are secured therein by clamp plates 68, secured to the face of the block 67,

and insulated from the brushes by the sheets 69 of insulation. Wires 71, secured to the inner ends of the brushes, pass out through the upper end of the cylinder 24, to connect to other parts, or connect the brushes in pairs, so as to connect the two contacts 60, upon which they are for the time bearing, and thus close-circuit between the two wires attached respectively to the outer ends of said contacts. The blocks 67 are fastened to the face of the arms of casting 70, secured to the shaft 62.

By properly connecting the contacts 60 to the circuits to be controlled, or to one another in rows, or in any desired relation, and by proper connection of the brushes 61 to one another, or to other parts through the wires 71, the device may be used for the primary connector, the secondary connector, the interconnector, the rotary switch and the signal transmitter controller, or for other parts, although for some of these parts not all of the contacts and brushes need to be utilised.



Plan.
FIG. 172.

The movement of the shaft 62 may be controlled in any desired way, as for instance by means of an electro-magnet 14 operating on a clutch between the wheel 63 and a suitable driving power.

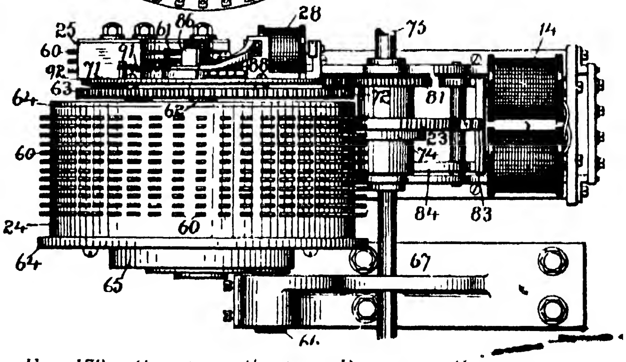


FIG. 173. CYLINDER SWITCH, REGISTER, CONTROLLING MAGNET AND MECHANISM CONNECTED THEREWITH. (LORIMER AUTOMATIC SYSTEM.)

The Clutch.—The clutch and gear is of the following construction (Figs. 172 and 173); 72 is a wheel gearing to wheel 63 upon the brush-carrying shaft 62. The shaft of wheel 72 carries a wheel 82 geared through idler wheels, with a wheel 81 rotating loosely on shaft 75, and having clutch control disc 23 fastened to its hub. The edge of the disc is cut or notched to permit the entrance of a dog 83, carried by elbow lever 84. An electro magnet 14 operates the lever and brings a serrated wheel 76 into engagement with a serrated wheel or disc 74 keyed to a power-driven shaft 75. When the wheels are engaged power is transmitted to the wheel 72, and wheel 63 of the brush-carrying shaft, from shaft 75 through wheel 78 on the same shaft with wheel 76, through an idle wheel to wheel 79, and a second wheel 80 on the same shaft with 79, and gearing to the wheel 72. Wheels 76 and 78 are mounted in a pivoted frame, which also carries the idler wheels, and is operated by a roller on the end of armature lever 84. As soon as the magnet causes the clutch to engage, the dog 83 rides on the continuous edge

of the disc 23, between notches, and keeps the clutch engaged until a notch frees the lever 84, and the clutch will then be disengaged if the magnet be then de-energised, and the wheel 72 and disc 23 will stop. A momentary action of the magnet will lift the dog out of the notch in the disc and immediately set the parts revolving. The notches are so spaced as to cause the cylinder brushes to advance any desired number of whole steps, depending upon the space between the notches.

The disc shown is notched suitably to bring the brushes to rest in 11 different positions, namely, normal or N, 0 and 1 to 9 inclusive, and then to cause the brushes to make a three-quarters revolution without stopping. This arrangement is suitable for the primary connector, or secondary connector, when the contacts are arranged according to the decimal system. When the dog is lifted from the last notch of the group shown, the disc and the brush shaft will make three-quarters of a revolution without stopping, until the dog finds the normal, or first notch of the group, when it will come to rest.

The Register.—This is constructed as shown in Figs. 172 and 173; 25 is a sector of insulating material like plaster of Paris in which any desired number of rows of contacts 60 are secured, and in position to be engaged by a set of brushes 61, as many in number as the rows of contacts. Brushes 61 are mounted in an insulating block secured to a support 86, that in turn is fastened to an escapement sector 87. When the register is used in connection with the cylinder switch, it is preferably mounted on a plate 92, secured to gear wheel 63 so as to revolve with the brushes of the switch cylinder.

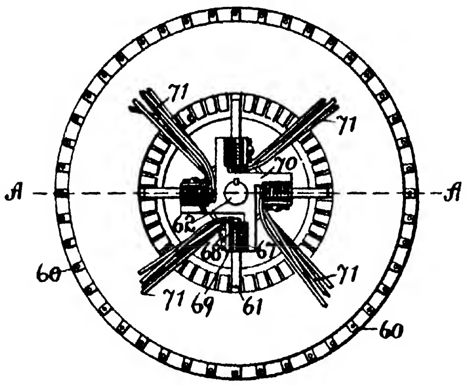


FIG. 171. PLAN OF CYLINDER SWITCH SHOWING BRUSHES. (LORIMER AUTOMATIC SYSTEM.)

Each row of sector contacts may consist of a normal (N) and 10 other contacts numbered 0 to 9 inclusive, which is sufficient for the primary connector. In the case of the secondary connector an additional contact, which is a "dead" contact, may be provided between the N and 0 contacts for a purpose to be described. A spring 88, secured at its free end to a strap wound around the hub of the escapement sector, tends to turn the sector in the direction of the arrow, and cause the brushes to move one whole step for each to and fro movement of the scape lever 89, which is moved in one direction by the armature of magnet 28 adapted to engage an arm 90, and in the other by a spring 95.

The scape teeth and pallets are so formed that the scape sector may be forced back to zero position when the support plate 92, upon which the register is mounted, is rotated by the superior force of the driving power from shaft 62, thus bringing the lug 93, depending from the sector through an opening in the plate 92, against and past an obstruction, such as a post 94 upon the fixed cylinder 24, or other fixed support. The pivotal centre of the sector is eccentric to the centre upon which the plate 92 turns, so that by proper adjustment of the overlap of the lug 93 and post 94, they will clear one another at the instant the sector brushes reach the normal position, and the support 92 may then continue its forward movement around to normal, ready for another operation.

The desired connections between cylinder brushes and register brushes may be made by wires 71 (see Fig. 174) which are sufficiently flexible to allow for the comparatively small relative movement of the parts.

Divisions.—The construction of the various portions of the connecting apparatus in one division of a section, and the general connections and functions of the same are as follow :—

1. *Primary Connector.* For each primary connector the apparatus described in connection with Figs. 172 and 173 may be utilised without material alteration. This device places any sub-station of the section on which it is located, in connection with the other portions of the apparatus in the same division. The two wires 1 and 2 of each line are connected to two contacts 60 assigned to it on the switch cylinder, by branch wires as indicated in Fig. 175 at (*d*), where one such line is shown. In addition to two-line contacts for each line a guard contact is provided connected in a similar way with a guard wire 3, one for each line. Wire 3 is a local wire at the central station.

2. *Rotary Switch.*—This is constructed from the cylinder switch previously described by connecting brushes in pairs to form bridging brushes, and by connecting up the contacts to one another and to the exterior circuits in the manner indicated in the diagram, Fig. 175 at (*e*).

The rotary switch completes its action, or moves from normal around to normal, by making a half revolution of the brush-carrying shaft, and in such half revolution it assumes seven positions of rest, as indicated by the Roman numerals I. to VII. inclusive at the top of the diagram. The brushes move over two of the contacts 60 in making one step ; if a clutch and gear, such as already described, be employed, the disc 23 would then have its notches spaced apart twice the distance of those indicated in the case of the primary connector. Since the switch repeats its operation twice in a revolution, the disc has two sets of notches as indicated. In the figure the dog engages with the normal notch of one group and the brushes are in the corresponding normal position.

The principal functions of the rotary switch are as follows :—

When the rotary switch of the seized idle division starts, it breaks its own clutch magnet circuit, thus isolating it from interference, and immediately closes a circuit or circuits over which the primary connector is adjusted. It also energises the clutch magnet for the primary connector and starts the device termed decimal register controller (Fig 175, *b*) which, by means of the register magnet, adjusts the brushes thereof to the position corresponding to the tens value of the number of the sub-station calling.

Immediately thereafter it starts the decimal indicator (Fig. 175, *a*) from the position of rest, which it had assumed by the initial signal from the calling sub-station, so that it may revert to the common use of other sub stations in the same section, and also completes the substitute connection for keeping the guard wire 3 of the calling sub-station charged. It also, at this stage of the operation, prepares the circuit over which an interconnector (*g*) of the same division may be started or operated, and further prepares the circuits over which connecting apparatus of the same division is operated or controlled by the signal transmitter controller (*f*), for the purpose of adjusting them to position for finding the circuit of the called line in the same or any other section. Further, it closes connections for charging the guard circuit of the sub-station called, upon the called sub-station's section, as soon as connection has been established therewith, but first closes a test circuit, by means of which the operation of the apparatus is controlled in such manner that if the line wanted be already in use, the

apparatus would be automatically prevented from coming to position for establishing talking connection therewith.

If the line wanted is found to be idle, the rotary switch charges the guard circuit of said line, and closes circuits whereby the calling sub-station may signal the called sub-station, when communication may be carried on. At the conclusion of the conversation the rotary switch moves to break such circuit, and closes others, whereby directly or indirectly the parts may be restored to normal position.

3. *Signal Transmitter Controller.* This device provides or produces electric impulses which operate or control the signal transmitter, the contact arm of which moves over units, tens, hundreds and thousands sets or segment of contacts. It also provides the stepping or controlling pulses for operating the thousands register and interconnector register of the same division and the secondary connector seized upon any division of the same or any other section.

This device consists of the switch cylinder previously described, and utilises six horizontal rows of contacts and three pairs of bridging brushes connected up as shown in Fig. 175 (*f*). The two upper brushes operate as an impulse generator to actuate or control the signal transmitters. The two middle rows simultaneously control the action of the thousands register, the interconnector register and secondary connector successively, and the two lower rows operate to close the circuit for coils that temporarily hold up the relay armature of the signal relay 215, and for other purposes.

N is the normal position of the signal transmitter controller brushes, in which position, after making two whole revolutions, the upper pair of brushes complete the signalling and talking circuit.

The signal transmitter controller has three positions of rest; the first is the N or normal position; the second position is indicated at SN, or sub-normal position, just before the end of the first revolution; and the third position is a second sub-normal position on the same contacts, just before it completes the second revolution and reaches normal again.

4. *Interconnector.*—The main function of this device (Fig. 175, *g*) is to establish connection with that section of the exchange to which the called subscriber's line is connected, and to seize upon an idle secondary connector in that section. The number of interconnectors in each division corresponds to the number of thousands of subscribers in the exchange.

5. *Secondary Connector.*—The secondary connector (*h*) is substantially the same as the primary connector.

The register is adjusted according to the tens value of the called subscriber's station number, and the cylinder brushes according to the units value of that number.

6. *Thousands Register.*—The thousands register, one for each division, is used only when two or more interconnectors are employed in each division. It serves to select or make connection with the interconnector controlling the connections of the grand division in which the called subscriber is located, and is provided with a number of contacts corresponding to the number of interconnectors employed in each division.

7. *Relays.*—The different relays employed in each division are indicated in the diagram (Fig. 175, *f*). 215 is a signal relay, 216 a release relay, 217 a ringing relay, and 220 a special relay.

20? is a generator of pulsatory or vibratory current, which is connected to the circuit, of the called subscriber by the operation of the relay 217 in any division; 205 is a non-inductive resistance shunting the coils of relay 217, so that they shall not interfere with

conversation;. 204 is an induction coil having two equal windings: 202 and 203 are sections of a continuous current generator supplying energy for various operations, and to which connections are made from the apparatus of each division in the manner indicated.

The combined voltage of the generators is used for some of the operations, but for conversation one battery or generator only is used.

Consecution Controller.—This device serves for the whole exchange, and renders the connecting apparatus on different sections, respectively, capable of operation only in succession or one at a time. Or, in other words, it spaces out the signals received on different sections at the same instant, in a manner to delay the action of the apparatus of one section, so that it can only operate after the other has progressed to the point where interference or confusion cannot result. The special object is to prevent confusion if two subscribers on different sections should attempt at the same instant to connect with the same subscriber, or with two different subscribers, on the same section. Confusion by reason of two subscribers on the same section calling at the same instant is prevented by the decimal indicator, of which one is used for each section.

The consecution controller comprises a continually operating circuit changer, which intermittently, but successively, closes the operating circuit for some part of the apparatus for one section, and then in succession similar circuits for other sections (Fig. 176).

In connection with each circuit a device is provided whereby the closure is prolonged if, when first made, the apparatus on that particular circuit is ready to operate. Hence, the consecution controller may continue its revolution, and the apparatus be left free to act.

The circuits closed are those by which the interconnectors are started on their way to seize an idle secondary connector. The effect then is that one of two simultaneously calling lines will seize the called line first, and the other will get the busy signal tone.

430 is a continually revolving circuit changer arm whose contact springs sweep simultaneously over feed segment 432, and over a series of segments 431 insulated from one another and connected respectively with bus wires 57, each of which forms a common return bus for the starting magnet 21 of all the interconnectors for one section, and each of which is connected to the several divisions of a section by taps 56, which in turn may be common to the several interconnectors of each division.

Each circuit contains an electromagnet 218, which, when energised, closes at its front contact a connection independent of that through the segment to the battery or common return, thus preserving the circuit for the interconnector after the brush of the consecution controller leaves said segment. The breakage of the circuit at some other point in restoring the apparatus to zero de-energises the magnet 218.

The consecution controller operates at such speed as to render the apparatus of each section capable of operation at intervals of, say, every two seconds.

Decimal Indicator. One of these is used for each section for the purpose of giving control of the apparatus on said section to the various subscribers' lines of that section in succession, and permitting a line to seize upon one of the idle divisions or sets of connecting apparatus for use in establishing connection with the called sub-station.

The decimal indicator has a circuit changing arm which closes connection to the lines of the sections in succession. It also comprises devices, whereby the primary connector

of the seized idle division may have its brushes automatically adjusted to position for connecting the calling line with the other parts of the apparatus in a division. For this purpose the decimal indicator embodies additional circuit-changing arms and divided contact rings, one termed the "units" ring and the other the "tens" ring.

Preferably the decimal indicator constantly revolves and is automatically brought to rest by a signal from the calling sub-station. As soon as the division of connecting apparatus seized by that station has passed beyond the point where it may be seized from some other calling sub-station the decimal indicator resumes its revolution. The circuits of the decimal indicator and control magnets associated therewith are shown in Fig. 175. The decimal indicator also has a circuit changing arm and a divided contact ring with segments, one for each line, whereby a guarding potential may be established on the guard contact of the calling line on all the primary connectors of the section. The mechanical construction may be such as shown in Fig. 177.

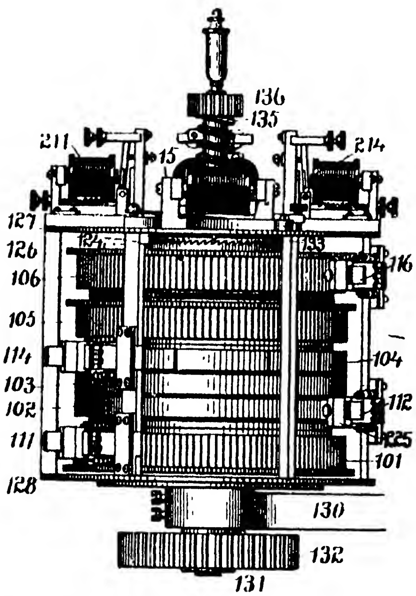


Fig. 177. Decimal Indicator. (Lorimer Automatic System.)

101 is a divided line contact ring having one contact or segment for each line of the section. Said segments are mounted upon a backing plate or ring, and clamped and insulated from one another, as shown in the vertical section, Fig. 177, in a manner similar to the segments of a commutator for a dynamo.

106 is the guard contact ring also containing as many segments as there are lines in the section, and each connected to its appropriate guard wire.

102 is a continuous feed ring connected with a relay contact lever by brush 112, and joined by wire 230 with devices for bringing one of the divisions of connecting apparatus into operation.

103 is a continuous battery feed ring through which, by means of brush 113, current is supplied to the circuits passing through the decimal indicator.

105 is the divided "units" contact ring, and 104 the divided "tens" contact ring.

The tens contact ring 104 contains ten segments of equal length, and its individual segments correspond respectively to the different values of the numeral in the tens decimal of the sub-station numbers.

The units contacts ring contains 100 segments corresponding to the 100 units of the sub-station numbers, and is divided into ten groups of ten each, the similar contacts of which groups are connected together; that is, the No. 1 contacts of all the groups are interconnected and, similarly, the No. 2 contacts are interconnected, to form in effect ten groups of contacts whose individual members are interspaced with one another. Each group of 10 contacts occupying the arc or portion of the units ring corresponds in position with one of the segments in the tens contact ring, so that the brush riding on its units contact ring may make connection with a units contact of any value from 0—9 inclusive, at the same time that

another brush makes contact with a segment of any value in the tens ring. Hence, any number from 0 to 99 may be represented as to its tens and units value by a brush riding upon the tens contact ring, in conjunction with the brush riding over the units contact ring, the number so indicated depending upon the circumferential position of the two brushes at any instant.

The several segments of the divided tens ring 104 connect, by cable 185, with the device termed the "decimal register controller." Through the latter device the adjustment of one part of the primary connector is accomplished. The 10 interconnected groups of contacts on the ring 105 connect by a wire 119 with a set of 10 contacts on each primary connector of the several divisions of connecting apparatus for a similar purpose.

All of the No. 1 contacts of the 10 several groups are joined to one wire of said cable, and all of the No. 2 contacts of said groups to another wire, and these wires represent each a different decimal value in the units place. Each connection to a wire of cable 119 may be obviously made by simply connecting one of the contacts of the group representing the one value.

Mounted upon the plate 127 is a stop magnet 15, the armature of which is furnished with a dog adapted to engage with a crown stop ring 124, having 100 teeth, properly located, to cause the brushes to come to rest upon a contact segment when the dog is forced down into engagement with the ring by the action of the magnet. The blade spring keeps the dog normally raised, but the moment the magnet is excited the plate carrying the dog and the brushes comes to rest, although the shaft 131 which drives the brush structure may continue to revolve.

The relays 211, 213, 214, whose coil and contact stop circuits are connected with the brushes shown in the diagram, are also mounted upon the revolving structure, thus dispensing with the necessity for feed contact rings which would be required if they were mounted upon an exterior fixed support. Relay 211 is connected to the brush 111 bearing on the line contact ring 101, and may be operated from any sub-station of a section as soon as the brush 111 finds the line contact of that sub-station in ring 101. Relay 211 controls the action of the clutch magnet 15, and relay 214 serves to charge the corresponding contact for the sub-station calling on the guard ring 106.

Decimal Register Controller.—One of these is used for each section. This device (*b*) acts in connection with the decimal indicator to adjust the primary connector into position corresponding to the "tens" value of the calling subscriber's number, and the several circuits in cable 185, leading from the "tens" indicating ring of the decimal indicator, operate as tests circuits, which determine the number of impulses which shall be sent by the decimal register controller over the wire 187, which runs through all divisions and is tapped at each primary connector to the register magnet 29 thereof.

The decimal register controller is started directly or indirectly in response to a signal received from the calling sub-station, and when started revolves until it finds a wire of cable 185 rendered alive by contact of brush 114 with the tens ring in the decimal indicator. It then begins to send pulses into the magnet 29 of the primary connector in the division seized.

Division Starter.—This device (Fig. 175, *c*) responds to a call or signal from any sub-station of a section on which it is located for the purpose of making one of the normally idle divisions of connecting apparatus operative. If 10 sets or divisions of connecting

apparatus are provided on a section, the division starter will have 10 starting positions. When it starts and seizes an idle division it automatically comes to rest again in position favourable for starting another idle division, when the call comes from another line on the same section.

When any division is in use, the starter is caused to pass the stop position corresponding to said division by devices operating automatically. But when the division is idle the starter stops in position ready for starting said division.

When the division starter moves from any of its positions of rest, it starts the rotary switch of the corresponding idle division by closing the circuit of the clutch or starting magnet for the switch or other portion of the division. The division starter is started by means of a clutch or stop magnet 16, brought into operation at about the time the decimal indicator comes to rest. For this purpose the circuit of the clutch magnet 16 may be closed by the line relay which responds to a call from any sub-station of the section.

Sub-station Apparatus. At each sub-station an automatic signal transmitter is provided for setting the central station apparatus into position to make connection with the line called. An indicator is used at the sub-station having indicator buttons or levers corresponding to the thousands, hundreds, tens and units of the decimal system. By setting these, to indicate the number of the sub-station wanted, the apparatus is prepared

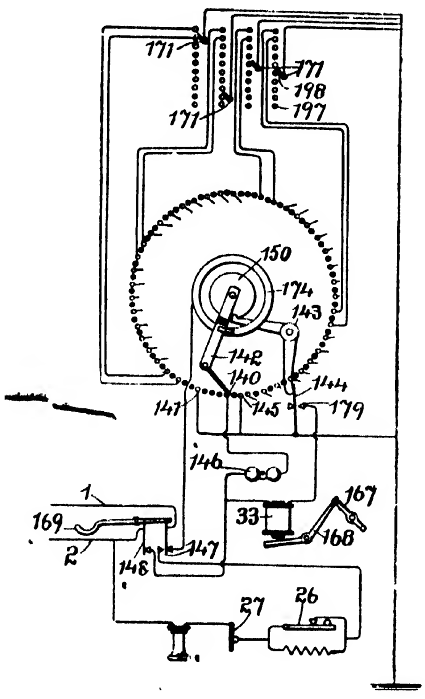


FIG. 178. LORIMER AUTOMATIC INSTRUMENT CIRCUIT. (WITH KEYS.)

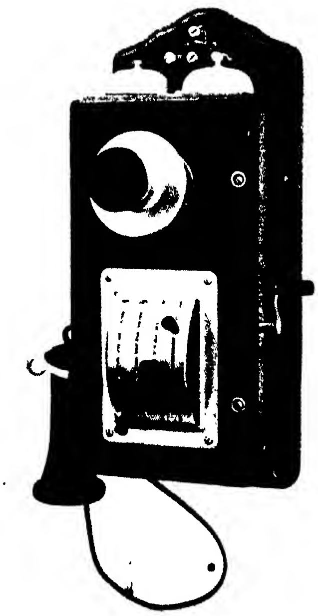


FIG. 179. SUBSCRIBER'S INSTRUMENT AS USED AT HEREFORD. (LORIMER SYSTEM.) (WITH LEVERS.)

so that the signal transmitter will automatically send the signals required for making connection with the line to which the number indicated is assigned (Fig. 178).

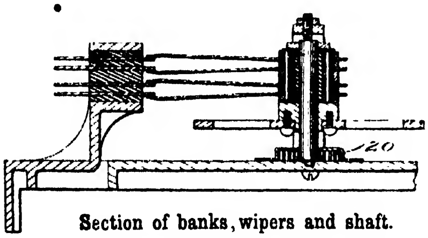
The switch and the signal transmitter are so constructed and combined that the switch cannot change its position while the transmitter is sending the call, and so that also the signal transmitter cannot send its signal if the switch is out of proper position. Also the signal transmitter is designed to send an initial signal in the manual operation of bringing it into action. Fig. 179 shows a general view of a subscriber's instrument.

Section 74

THE AMERICAN AUTOMATIC TELEPHONE CO.'S SYSTEM

Unlike the other systems described, which use a dial with ten points only, this uses a dial with 50 points, and the switches also have 50 points, and have rotary motion only.

The dial is marked with both letters and figures. The letters advance in value by fives, A being 1 impulse, B 5 impulses, C 10, and so on to the last letter, which represents 45. The figures 1 to 50 call the two final digits, and in one case are translated so as to call into the second half of the hundred.



Section of banks, wipers and shaft.

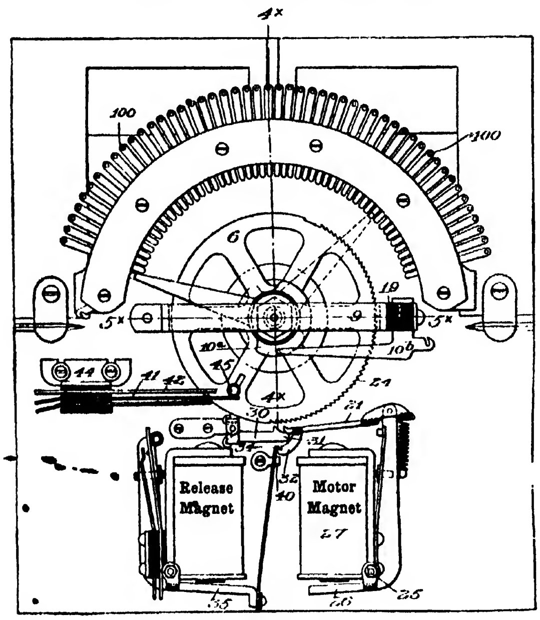


FIG. 180.—AMERICAN AUTOMATIC CO.'S CONNECTOR.

Six call-finders are associated with a group of 50 calling lines. The selector banks are divided into 10 groups of five sets of terminals—five lines to 10 groups of 500 lines. The second selectors find the particular group of 50 lines, and the connectors find the particular line in the group of 50. The selectors are called by letters, only the connector being operated by a number call from the dial.

The selector and connector are generally similar in construction. Each has a level of three terminals and 50 sets of such terminals in the arc.

Each line has a line and cut-off relay, the former when energised by the removal of the receiver to call completes a starting circuit which gives the call finder its first impulse, the further impulses depending on the circuit condition of the tabs with which the wipers make contact. Fig. 180 shows two views of a connector. The wipers are moved against the tension of a coiled spring 20 by the motor magnet.

The operation of the circuits (Fig. 181) is as follows :—

When the receiver is lifted to call, a circuit is completed through the line relay LR as in the manual C.B. system.

A circuit is then completed from earth through front contact of line relay LR through motor magnet M, battery and earth, and, in parallel, slow-acting relay SA, which is in series with winding of connector relay A to battery and earth.

The motor magnet steps the answering connector AC wipers from normal to the first set of contacts, in its search for the calling line.

The slow-acting relay SA is retained if the first line is idle because a circuit is completed from earth on back contact of line relay LR, contact stud and wiper *a a'*, front contact and winding of relay SA and winding of relay A to battery. Relay A cuts off relays C and D and battery to prevent interference and clicking whilst wipers are passing over intervening contacts.

Also there will be a circuit from earth on back contact of line relay, contact stud and wiper *a a'*, front contact of relay SA, motor magnet M to battery, so that the wipers will be moved to the next set of contacts.

If the second set of contacts appertain to the line calling the motor magnet will come to rest as there is no earth on the back contact of the line relay.

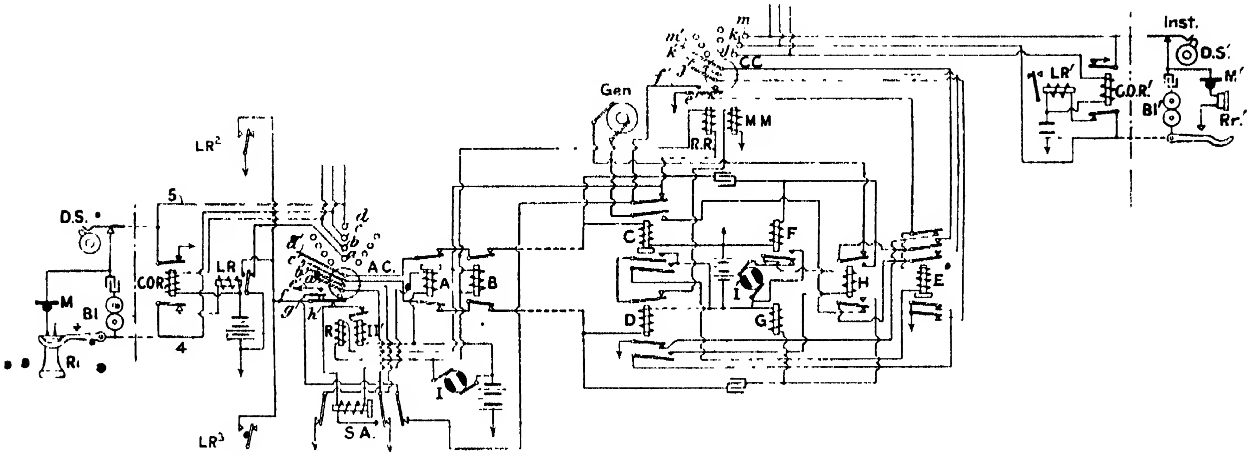


FIG. 181.—CIRCUITS OF AN AMERICAN AUTOMATIC CO.'S SYSTEM.

Relays SA and A are likewise de-energised. With the first movement of the wiper the upper off normal spring *f* is put to earth.

The following circuits are now established: Wire 5 has been extended by contact and wiper *d d'*, upper contacts of A and B relays, through winding of relay C to earth; wire 4 by contact and wiper *c c'*, by lower contacts of A and B relays through winding of relay D to battery and earth. Relays C and D are therefore energised and C also causes relay E to be energised. The cut-off relay COR of the calling line is energised and cuts off the line relay LR, the circuit being from earth by left-hand contact of relay SA, wiper and contact *b'b* through winding of COR to battery and earth. The back contact of the line relay is again connected to earth.

The caller now revolves the dial switch DS which intermittently opens the circuit and correspondingly de-energises relay HD intermittently. Relay C is slow acting and does not respond to the impulses.

Relay D as it de-energises completes the circuit intermittently through the motor magnet from earth through winding MM, through upper contact of relay D, front lower contact of relay C to battery and earth and the wipers of CC are stepped according to the number of impulses sent.

The first movement of the calling connector CC cuts earth off relay E, but as it is slow acting it is retained by the circuit through upper contact of E and contact on D to keep the circuit to line open to prevent clicking and interference from generator. When relay D ceases to pulsate E is de-energised.

When the wipers come to rest (if the line is disengaged) a circuit is completed through the cut-off relay from earth by bottom outer contact of E by short wiper and stud $j'j$ through COR to battery and earth and the line relay is cut off.

The generator is connected to line through the upper contact nearer core of relay C, lower back contact of relay H, upper back contact nearest core of relay F through middle wiper and contact $k'k$ to line, through bell and condenser, by other wire to contact and long wiper $m\ m'$, back contact of middle upper springs relay E. upper back contact relay H to generator.

As the circuit of relay H is from earth by lower contact nearer core of relay E. lower front contact of relay D through winding H. back contact of relay F. interrupter I, battery and earth, the generator current will be applied intermittently to line.

When the subscriber answers, a circuit through coils F and G is completed through the telephone and relay F is energised (when relay H has intermittently closed the circuit). This cuts off the ringing current and completes a circuit as before through winding H but to battery without interrupter and the line is joined through by the under contacts of relay H.

Current to energise the microphone of the calling line is then fed through relay windings C and D and that for the called line through F and G.

When the calling subscriber replaces his receiver the circuit is opened and relays C and D are de-energised.

A circuit is then completed through the release magnet RR, from earth e' at off normal spring f' of calling connector, upper outer contact of relay C, through RR, interrupter I to battery and earth. The connector is therefore returned to zero. The generator circuit is broken at relay C whilst the wipers pass over the contacts.

There is also a circuit from earth contact, off normal spring of call finder, through right-hand back contact of relay SA, upper outer contact of relay C, through relay B and release coil R in parallel, interrupter I to battery and earth so that the call finder is also returned to zero. Relay B cuts off battery through relays C and D to prevent interference whilst wipers are passing over contacts.

RELAY SYSTEMS

The building-up and connecting is carried out entirely by relays.

A link method of connecting (equivalent to a double cord arrangement in manual practice) is used.

COMPANIES USING THIS SYSTEM ARE:

NYA AKTIEBOLAGET AUTOTELEFON BETULANDER, STOCKHOLM.
THE RELAY AUTOMATIC TELEPHONE COMPANY, LIMITED, LONDON.

The British system is based on the Betulander.

Section 75

THE RELAY AUTOMATIC TELEPHONE CO.'S SYSTEM

Relays, only, are used for all switching operations.

A connection between an outgoing and an incoming line is completed over a *link*. The *link* is a short connecting circuit which, on one side, connects with the incoming line and, on the other, connects with the outgoing line. It is thus equivalent to a double cord circuit on a manual equipment.

The connection to an idle line in a plurality of outgoing lines in a group is determined by a *self-searcher* in combination with common apparatus.

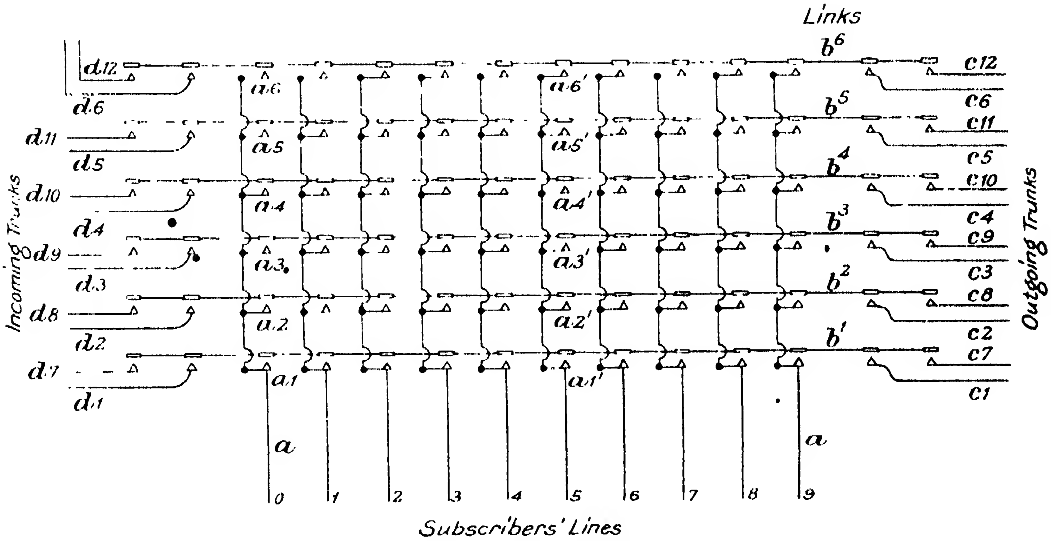


FIG. 182. RELAY SYSTEM. SUB-GROUP OF TEN SUBSCRIBERS' LINES. (SINGLE-LINE DIAGRAM.)

Link-connecting is shown diagrammatically in Fig. 182, in which *a*, *a*, represent subscribers' incoming lines; *b*, *b*, links; *c*, *c*, outgoing trunks; and *d*, *d*, incoming trunks. The subscribers are usually arranged in sub-groups of 10 lines. The 10 lines of the sub-group have access to six links usually. Each link has access to one or two, usually two, outgoing trunks, and the same number of incoming trunks has access to the links for incoming calls.

Each subscriber's line is, therefore, equipped with six link-connecting relays, by which it may be connected to any one of the six links automatically, at the preselector or predigit stage.

Each link has four relays associated with it, by which it may be connected with one or other of two outgoing, or one or other of two incoming trunks. Each link is, therefore, multipled over 10 subscribers' lines and over, say, two outgoing and two incoming trunks.

In diagram, Fig. 182, each *make* contact represents a relay. When a relay is energised

on a call being made, the contact is closed. If, therefore, contact $a3'$ and contact $c3'$ be closed, subscriber No. 5 will be joined through to the outgoing trunk $c3$, or, if contact $a3'$ and contact $d9$ be closed, subscriber No. 5 will be connected over the incoming line $d9$.

The method of determining which link-connecting relay is to be utilised for completing a connection is shown typically in Fig. 183.

R′, R2, R3, and R1′, R2′, R3′, represent relays associated with two subscribers' lines, three only being shown instead of six.

A circuit-determining relay M is associated with each link, and a wire from each line-link relay R in the same level (*e.g.*, R′ and R1′) is connected to a normally insulated contact on relay M.

The circuit of the M relays is so arranged that the M relay nearest the base is first energised over circuit 1, then, if that is in an open circuit, by contact *c* being open, and, therefore, unenergisable, the second M relay is energised over circuit 2, and so on. When the contact K is closed all the vertical row of relays R are connected to earth, and the M′ relay energises, but R′ only is energised over circuit 4. If the lower link is busy the contact *c* will be open (by means not shown) and M2 will energise, and so on.

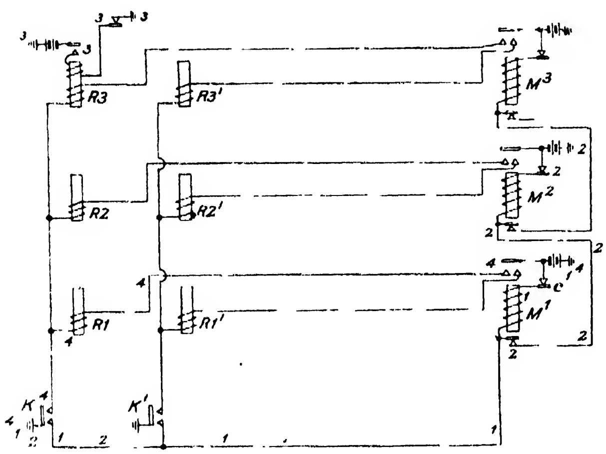


Fig. 183.—Self-searching (R. A. T. Co.) Explanatory Diagram.

The circuits of six relays in a vertical row will be partially completed by contact K, and 10 relays in a horizontal row will be partially completed by a relay M, but only the relay R at the point of intersection will energise to complete a connection between a calling line and an idle link. When a call is made equivalent action to that of contact K occurs, such circuits being completed momentarily, but a holding circuit corresponding to circuit 3 is established to maintain the connection.

When a receiver is lifted the calling line is automatically extended, by the preselector group of relays, to a so-called *recorder*. Each line has access to a plurality (usually two or three) of recorders, which are common to, say, 100 subscribers, the exact number depending on the traffic. The recorder receives the impulses from the dial and, according to the number of impulses in the digit, builds up a circuit corresponding to the digit which, by means of a *marker* relay, initially energises the called subscriber's line relay, to start a backward selection to connect with the calling line. The recorder may respond to one, two or three, or even four digits, before establishing the initially energising circuit. The *marker*, which is engaged for one-tenth of a second per call, is common to a 1,000-line group.

The recorder is not directly associated with the caller's line until the first impulse is sent. Two parties calling at the same time are extended to the same recorder, but the first

impulse sent will determine with which line it is to be directly associated, the second calling line then being transferred to another recorder.

In an exchange of 100 lines, two-digit recorders will be used, and tens marking relays will then extend the initially energising circuit to the desired sub-group of lines.

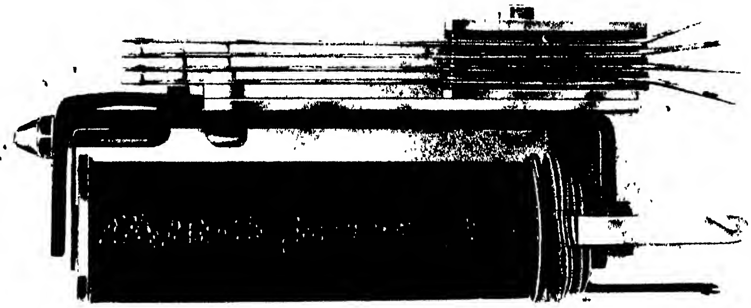


Fig. 184. The Relay. Normal or De-energised. (Actual Size.)

In a system of 1,000 lines, a three-digit recorder will call into any group of 100 lines, by means of hundreds marking relays.

A group of from 40 to 80 trunks (the number depending on the traffic) is used, in common to connect into the group of 1,000 lines.

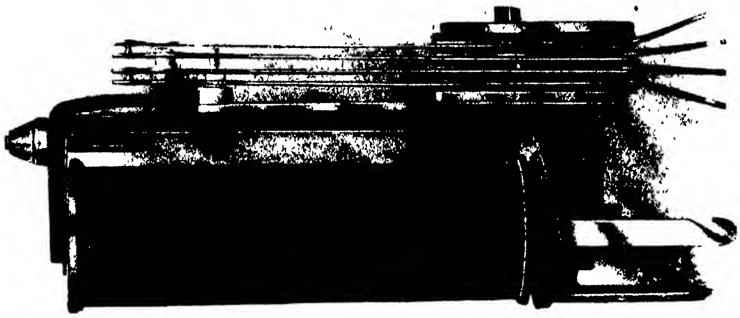


Fig. 185. The Relay. Energised.

In the recorder a *make* relay energises at the beginning of the impulse, and a *break* relay (previously energised) de-energises at the termination of the impulse, and connects the impulse circuit through to the next relay.

Relays.—These are shown in Figs. 184 and 185. In the former the relay is shown in its normal or de-energised condition, and in the latter in its energised condition. The armature, in shape, is practically a right angle suspended on the end of the core magnetic-return plate. Between the core end and the armature a tongue of non-magnetic material is suspended to

prevent the two magnetic faces touching, and to regulate the travel of the armature. The soldering tabs have a flat ring-shaped end, so that they can be threaded over the core, or an

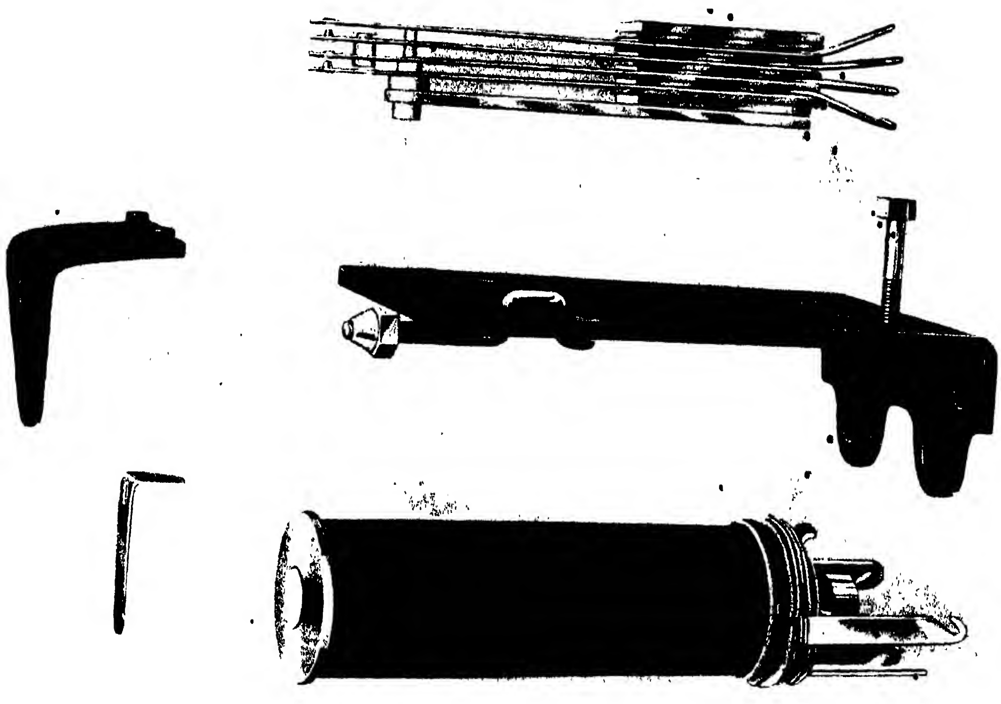


FIG. 185A. R. A. T. CO.'S RELAY, BEFORE ASSEMBLY.

extension of the core, from which they are insulated. The necessary number of tabs are separated from each other by washers as shown. The contact pressure of the springs (make and break) is $1\frac{1}{4}$ ounces (35 grammes).

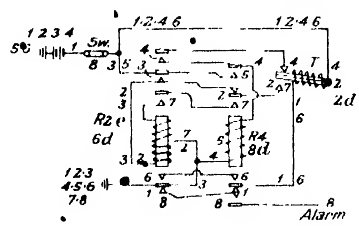


FIG. 186. A THERMOSTATIC TIMING DEVICE CIRCUIT (R. A. T. CO.).

Such a relay allows of wide variation of the dial speed.

The relays are wired in units in the factory and are connected to strips of soldering tabs.

Thermostats.—These are introduced as timing devices to prevent common apparatus being held longer than a predetermined period. They are also used as current interrupters. The heating part consists of bimetallic strip on which wire is wound and connected to a control circuit. They can be adjusted to operate at any desired period of time. A special feature of this design is

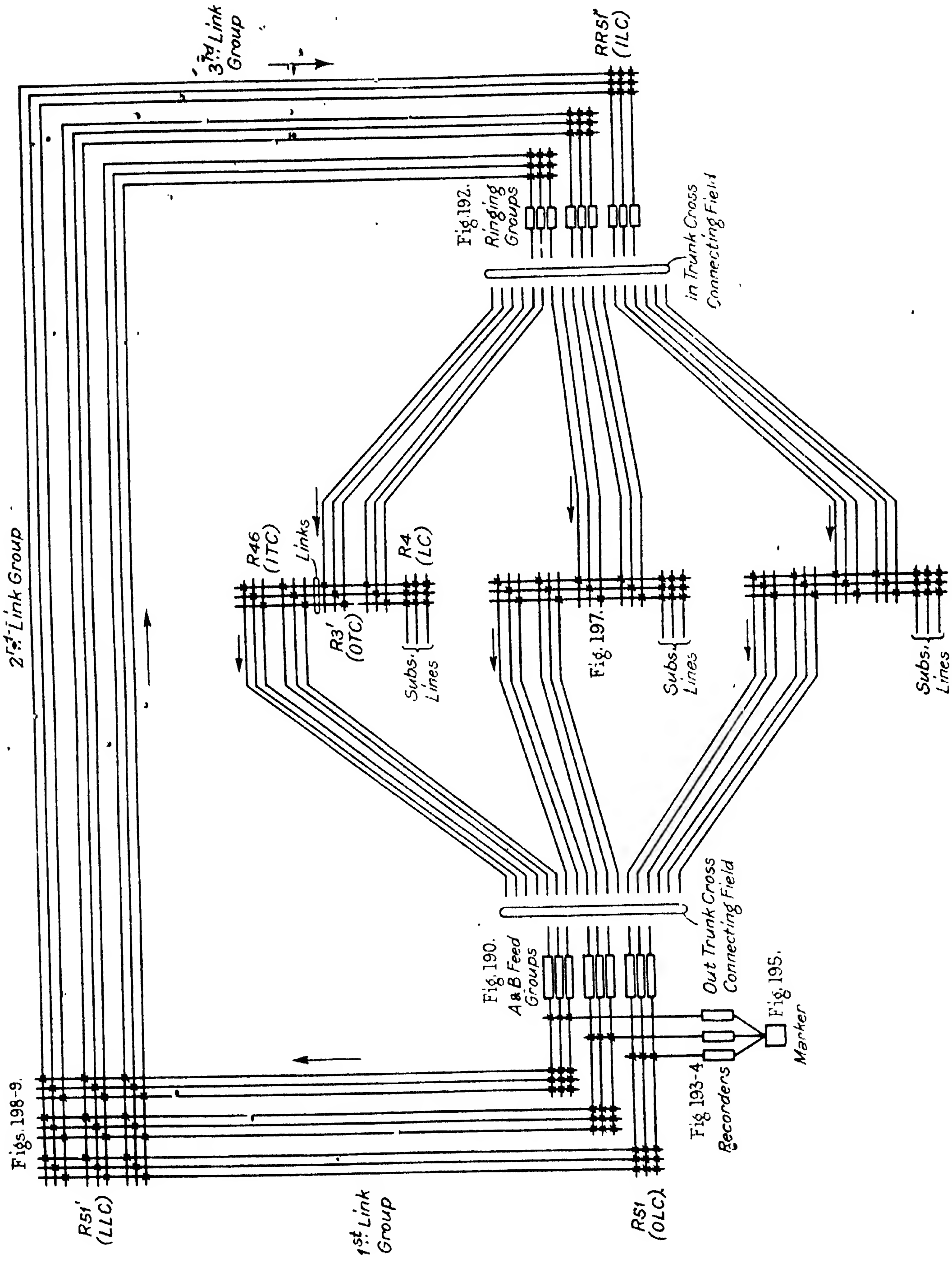


FIG. 187.—SINGLE LINE DIAGRAM OF A 1,000-LINE R. A. T. CO. SYSTEM
The figure numbers in this diagram refer to the corresponding circuit diagrams.

that the adjacent operating springs are also made from bimetallic strip, so that all are equally affected by variations of temperature of the surrounding air.

Fig. 186 shows a thermostatic timing device circuit to give an audible or lamp signal when an abnormal condition has existed for three minutes. This result is obtained by the interaction of two relays and the thermostat. The circuits are numbered in the order of operation, and will be readily followed without detailed descriptive matter. The thermostat operates twice, once to energise relay R2, and on de-energising to operate relay R4. On the second energisation, the second winding circuit of the differential relay R2 is completed to de-energise R2 when the alarm circuit 8 is completed. When the fault is removed, or the circuit opened, as by the switch 8, circuit 5 is opened, and R4 de-energises to restore the device to normal.

Trunking Scheme of a 1,000-line Exchange.—In Fig. 187 is shown such a scheme in which one line indicates a circuit.

This relay system differs from all the other systems described in that the line switch unit, or preselector, is common to both outgoing and incoming connections. A distributing board is therefore provided, so that the traffic may be regulated in both directions.

Connection is made to a group of 1,000 lines over a common group of trunks, the number depending on the traffic requirements.

The common recorder takes in and stores the impulses of the three digits of the called number, and after the last impulse has been received, an initially energising circuit (the marking circuit) momentarily energises selecting and connecting relays to establish the connection from the battery feed to the called subscriber, ringing current then being applied to the latter.

On this diagram the relays are indicated by x's at the intersection of lines between which connection is to be made. Reference is made to the corresponding relays on other diagrams by the use of similar symbols, so that they can be readily identified.

Detailed circuits of the subscriber's unit will be found in Fig. 197, and its circuits in connection with the system in Figs. 188 and 189.

The outgoing trunks pass through a cross-connecting field before they connect with the feeder units (Fig. 190). Connections are then carried to the recorder-connector and recorder (Figs. 193 and 194). What have been called first, second and third links are then connected to, and these are described with their operation in Fig. 198. The so-called third links are extended to the ringing units (Fig. 192). The incoming trunks then pass through a cross-connecting field before being connected to the subscribers' unit (Fig. 189).

As will be seen from Fig. 187, and as has already been pointed out, the subscribers' lines are arranged in *sub-groups* of 10 lines, incoming calls to a sub-group being controlled by one common relay, and the outgoing calls by another.

Each sub-group has access by six *links* to 12 outgoing and 12 incoming trunks, each link having access to two trunks each way.

These outgoing and incoming trunks are multipled on a plurality of sub-groups so that they may be used in common to, say, 100 lines.

Should, *e.g.*, the two trunks by which a link has outgoing access be in use at another sub-group, that link is not available for outgoing calls.

The small size of the sub-groups and the limited access by links makes it imperative that a series of busy lines should not be in the same sub-group. Distributing facilities are therefore provided as shown. The " out trunk cross-connecting field " allows of rearranging the

lines in one direction, and the "in trunk cross-connecting field" for rearranging them in the other, as the calling rate per line varies from time to time, so that the calls from or to a sub-group do not rise above a predetermined figure.

The *recorders* are common to a group of lines. When associated with the feeder groups, as shown, two or three may serve a group of 100 subscribers, according to the calling rate. A *recorder-connector* is, however, associated with each trunk or feeder.

The *marker* is in turn common to all the recorders of a 1,000-line group, usually one only being provided in such a group. Each hundreds marker relay, therefore, controls access to 100 subscribers' lines.

SYMBOLS USED BY R. A. T. Co.

CIRCUITS.

A	"A" Line.
B	"B" Line.
T	Test.
H	Holding.
M	Marking.
I	Impulse.
OT	Out Trunk.
IT	In Trunk.
HD	Hundred.
TN	Ten.
1.6	1 and 6.
1—5	1 to 5.

RELAYS.

Subscribers' Unit.

LE	Line.
F	Fault.
CO	Cut-off.
LC	Link Connecting.
OTC	Out Trunk Connecting.
ITC	In Trunk Connecting.
LM	Link Marking.
OTT	Out Trunk Test.
ITT	In Trunk Test.
LB	Link Busy.

A and B Feed.

A	Calling Subscribers' Feed and Impulse Relay.
B′	Called Subscribers' Feed.
B″	Called Subscribers' Feed.
G	Guarding.
GX	Guarding Auxiliary.
R	Release.
ME	Meter.
BB	Busyback.
BBS	Busyback Starter.
RB	Reverse Battery.
IS	Impulse Series.
CCO	Condenser Cut-off.

Recorder.

P	Preparing.
BY	Busy.
RSR	Recorder Slow Release.
DC 1	Digit Control 1.
DC 2	Digit Control 2.

RELAYS—*continued.*

Recorder—continued.

DC 3	Digit Control 3.
DC 4	Digit Control 4.
MC	Marking Control.
MCX	Marking Control Auxiliary.
MCO	Marking Cut-off.
SB	Subscriber Busy.
SNB	Subscriber Not Busy.
MK 1	Make 1.
MK 2 etc.	Make 2 etc.
BK 1	Break 1.
BK 2 etc.	Break 2 etc.
DM 1	Digit Marker 1.
DM 2	Digit Marker 2.
DM 3	Digit Marker 3.
HD6C	Hundreds 6 Change Over.
TN6C	Tens 6 Change Over.
HD 1.6	Hundreds 1 and 6.
HD 2.7	Hundreds 2 and 7, etc.
TN 1.6	Tens 1 and 6.
TN 2.7	Tens 2 and 7.

Marker.

HDM 2	Hundreds Marking 2.
HDM 3	Hundreds Marking 3.
HDM 6	Hundreds Marking 6.
TNM	Tens Marking.

Trunk Connecting Group.

OTM	Out Trunk Marking.
OT-IT	Out to In Trunk Connecting.
ITB	In Trunk Busy.

Special Services.

DL	Dead Level.
MX	Manual Exchange.

Recorder Connector.

RC 1	Recorder Connector 1.
RC 2	Recorder Connector 2.
FI	First Impulse.
FICO	First Impulse Cut-off.

Ringing Group.

H	Holding.
RG	Ringing.
RT	Ringing Trip.
RTX	Ringing Trip Auxiliary.

Section 76

COMPLETE CIRCUIT OPERATION OF A THREE-DIGIT SYSTEM

Fig. 188 shows the connections through the calling subscriber's preselector unit, and Fig. 189 the same for the called subscribers' unit.

Fig. 190 shows the battery feed for the calling and called lines. Fig. 191 the circuit through the common group of trunks giving access to 1,000 lines. Fig. 192 shows the ringing unit.

Fig. 193 is the recorder-connector which is associated with each feeder unit. Fig. 194 is the recorder which is common to a plurality of subscribers' units. Fig. 195 shows the marker relays which are common to an office of 1,000 lines or less. Fig. 196 shows a repeater which may be introduced at the incoming end of trunks at a second office. The whole, with the exception of Fig. 196, show the connected circuits for a 1,000-line exchange. It is to be noted that the figure 1 is not used as the initial digit of a number, and that if 1 is called, the connection is released. This eliminates trouble from spurious impulses which may be sent by accidental movement of the switchhook, or other opening of the circuit.

The circuits are numbered in the order of operation, and are as follows :—

1. When the receiver is lifted, relay R′ energises.

2. The common outgoing test relay R2(OTT) energises.

3. Link marking relay LM′ energises if the first link is idle, and outgoing trunk-connecting relay R3′(OTC) energises.

4. Relay R4(LC) energises in the initially energising circuit.

5. The loop is extended to the impulse relay R5, which energises.

6. Guard relay R6 energises.

7. Second guard relay R7 energises.

8. Holding circuit for relays R4 and R3′, in which relays R8 and R8′ energise. The differential relay RR8 does not energise. R8(CO) opens circuit 1, and R′ de-energises. Circuit 2 open, and R2 de-energises. Circuit 3 open, and R3 de-energises (R3 was held energised over circuit 3′ after R8 energised). Circuit 4 open. Circuit 3 is also opened at R2 and R7. The common apparatus is thus free for other calls. The meter is biassed against the holding current.

8′. Balancing circuit for relay RR8.

9. Lamp L9 circuit.

10. Circuit through relay FICO, of recorder-connector, prepared.

11. R11(BBS) energises (slow to de-energise).

11′. Circuit completed through thermostat winding. This is the beginning of the predetermined period in which the connection must be completed.

12. Impulse circuit extended to the recorder-connector through the two windings of the differential relay R57. R12(F′) energises.

13. If the first recorder is idle, R13(P) and R13′(RC′) energise. If two subscribers call at the same time, both will be in parallel on this recorder, but the first to dial an impulse will associate the recorder directly with his line, and the other will be transferred to the next idle recorder.

14. Circuit 10 is switched to circuit 14 by relay R12 energising. R14(FICO) energises and opens one of the parallel paths to R12.

15. R13 energising connects battery to the recorder. All R15 relays (BK1 to 0) energise.

16. R16(DM′) and R16′(DC2) energise.

17. Alternative circuit for R16 and R16′.

18. R18(RSR) energises.

19. Lamp L19 glows.

20. R20(MK′) energises.

21. Holding circuit of R20. R15(BK′) de-energises as the impulse circuit is open at R12(F′).

The hundreds digit impulses are dialled. It will be assumed that No. 347 is being called.

On the first break of the loop R5 de-energises. Circuit 12 is open and R12 de-energises.

22. New holding circuit for R14 in which is the retaining winding of R13′(RC′) to associate the recorder directly with the caller. Holding circuit of R13(P) and winding of R22(BY), which energises and opens circuit 13, so that no other caller can have access to recorder No. 1. Circuit 20 is open, but is replaced by circuit 21.

23. At the end of the impulse, R5 energises and the impulse circuit 12 is extended by circuit 23 and R23(MK2) energises.

24. Holding circuit for R23 in which R24(DC3) energises.

25. If only one impulse is sent, R25 (slow to energise) energises over circuit 23 If there is more than one impulse, R25 has not time to energise.

26. If R25 energises, then R26(SNB) energises, opens circuit 22 and releases the recorder and its connector.

Should more than one impulse be sent, the second opening of the loop causes R5 to de-energise to open the impulse circuit 12—23, when relay BK2 de-energises. Circuit 21 is open, and R20 de-energises, and BK′ de-energises over circuit 15.

27. When the loop is again closed, R5 re-energises, circuit 12—23 is completed, and R27(MK3) energises.

28. R27 is maintained energised over 28—24 and BK3 de energises.

For additional impulses relays MK and BK 4 to 9 and 0 operate in a manner similar to that described.

When the hundreds impulses are completed, R5 remains energised, and R25(DC″) energises in circuit 25.

29. The hundreds relay R29(HD5) energises and opens circuit 16. R16′(DC2) and R16(DM′) de-energise and open circuits 26 and 29. All the MK relays de-energise, and all the BK relays energise. DC3 and DC″ de-energise.

30. R16′ re-energises in series with R20(DM2) over circuit 17—16–30. DC2 over circuit 21 connects earth to the MK relays. R20(MK′) energises, and is held as before. BK′ is transferred to and held over the impulse wire as before.

31. Holding circuit of R29.

The tens digit impulses are now sent in. The digit to be called is 4. These impulses operate the MK and BK relays, as before. MK4 and MK5 are energised and BK4 de-energises.

After the impulses R25(DC′) energises in circuit 25.

32. The tens relay R32(TN4) energises and opens circuit 30. R30(DM2) de-energises.

and circuit 30 is extended to DM3, which energises. DC2 de-energises and all MK relays. All BK relays energise. R24(DC3) de-energises. R25(DC') de-energises.

33. Holding circuit of R32.

34. R16'(DC2) energises and earth is connected to the MK relays. MK' energises and BK' is transferred to the impulse circuit. DM3 energises.

The units impulses are now sent in for digit 7. MK and BK relays respond as before, and MK7 and MK8 energises and BK7 de-energises.

After the impulses R25(DC'') again energises.

35. R35(MC) energises.

36. Holding circuit for R35.

37. Holding circuit for relays BY, P, etc.

38. R38(HDM3) energises, and totalising meter energises.

39. R39(MCX) and R39'(TNM) energise.

40. Holding circuit of R39. Circuit 18 is opened and R18(RSR) de-energises slowly.

41. R41(OTM) energises.

42. Initially energising circuit through differential relay MCO and R26(SNB). Called subscriber's line relay R42 and test relay R42'(ITT) energise.

43. Second winding of differential relay, which prevents its energising.

44. Holding circuit of R26(SNB).

Circuits 22 and 37 are open, and R22, R13 and R13' de-energise.

The recorder is returned to normal.

45. R45(OLM) energises.

46. RR46(ITM), R46(ITC), RR46'(LM') energise.

47. R47(LC) energises.

48. R48(SS) energises.

49. R49(ILM) energises.

50. Holding circuit for relay R49 (other ILM relays cut off) if the first circuit is idle.

51. R51(OLC), R51'(LLC), RR51(ILC) energise.

52. Holding circuit for R51, R51' and RR51, in which R52, R52' and RR52 energise. R52 opens circuit 45, and R45 de-energises. R52' opens circuits 46 and 49. RR52 opens circuit 46, but R46 is held energised in circuit 46'.

53. Holding circuit for R46, R47, in which R53(LB) and R53'(CO) energise. The line relay R42 de-energises. Circuits 46 and 47 are open, and RR46'(LM') and RR46(ITM) de-energise. Circuit 48 opens and R48 de-energises. Circuit 50 open and R49 de-energises (now in open circuit, so that the next call will energise a relay above). Circuit 51 open.

54. R54(RG) energises and lamp L glows.

55. Ringing current to called line and tone to calling line.

When the called subscriber answers R55 energises.

56. The short circuit about R56(RTX) is then opened, and that relay energises.

57. R54 (GR is made slow to de-energise) is then connected to the A wire, so that the differential relay R57(IS) energises, the other winding being insulated. Circuit 55 is open.

58. R58(CCO") and RR58(CCO') energises. R11(BBS) de-energises. Circuit 12 open, and R57(IS) de-energises.

59. R54 is maintained energised in series with R59, which energises.

60. Holding circuit for guard relay R6.

61. RR58 extends the calling loop 5 to the speech repeater, and R61 energises. Circuit 5 is open and R5 de-energises.

62. R62(ME) energises.

63. Holding circuit for R62.

64. R64(MECO) energises and joins the trunk through to the speech repeater. Circuit 59 open, and R59 and R54 de-energise and join the line through at the ringing unit.

65. R65(B″) and R65(B′) energise in the loop through the called instrument.

66. Holding circuit for R64.

67. Battery is reversed to the calling line, to remove the short circuit on call-office telephones and the like.

The talking circuit is now complete.

To Break Down the Connection.—When the calling receiver is replaced after conversation, R61 de-energises, then R65 and R65′, as the loop circuit 65 is open. Circuit 6 open, and R6(G) de-energises. Circuit 7 open, and R7 de-energises and opens circuits 10, 11 and 58 to release the connection to the called subscriber.

68. The lamp L8 is short-circuited, and the current through RR8 and circuit 3 thereby increased so that the meter M8 operates. M8 short-circuits its front winding and RR8 is unbalanced and energises. Circuit 63 is opened and R62 de-energises. Circuit 66 is opened and R64 de-energises, to totally break down the connection.

If the called subscriber had been engaged. When the initially energising circuit 42 has been built up, it cannot be completed, because the called subscriber's cut-off relay 53′ is energised. R26 will not energise.

69. R69(SB) will energise and open the two sides of circuit 23, when current will be through one winding of R57(IS), so that it energises. Circuit 58 will be completed and R58 energise. R59 will energise over circuit 59—12—23.

70. R70(BB) energises.

71. Holding circuit for R11 and R71.

72. A busy tone signal is given to the calling subscriber.

The differential relay MCO will energise, because it has current through the winding in circuit 43 only. This will open circuit 41, to de-energise R41. Circuit 25—26 is open, and R35(MC) will open the holding circuit 37—39—38, to release the recorder and the recorder connector.

Should a line become faulty and the line relay be energised. As no impulses are sent in the thermostat will operate and open the holding circuit, when the cut-off relay will de-energise. The line relay will be re-associated with the line and will energise. The fault relay F (which is energised in circuit 75 and held in 76) will connect the incoming marking wire to an operator or a tone signal, so that a caller will know that the line is out of order.

The relays DL and MX of the recorder shown unconnected. DL is the *dead-level* relay, and, when such circuits are required, an under contact on R16(DM′), corresponding to the digit allotted to such service, is opened to the HD relays and the latter wire replaced by a wire to the DL relay. DL then responds to the first digit associated with that service and completes a necessary marking circuit.

The M.X. (*Manual Exchange*) relay is associated with lines to the manual exchange, and is correspondingly connected at R16, according to the digit allotted to that service.

Section 77

IMPULSE AND SPEECH REPEATER (Fig. 196)

This is usually introduced at the incoming end of a two-wire trunk, and would be used in combination with Figs. 188 to 195 on a four-digit system. There would be a single-digit impulse recorder associated with the feeder unit and a three-digit recorder associated with this repeater.

The repeater would operate as follows :-

After the first digit is called, the feeder is extended to an idle trunk of the group corresponding to the thousands digit called.

R57 will have a winding connected to each wire of the loop, so that circuit 12 is extended to the repeater at the incoming end, and the impulse relay RR12 is energised.

81. The guard relay R81 energises.

82. The impulse circuit is through the differential windings of relay R82 to the recorder-connector and recorder, as described in connection with Figs. 190, 193, 194.

After the recorder has received the impulses of the final three digits, the initially energising circuit (42) is effective, as before, to extend the trunk to the ringing unit and to connect the called subscriber, through the subscribers' unit, towards the trunk.

82′. The called party is rung and, after reply, R54 is connected to the A wire. R82 is unbalanced and energises.

83. R53 and RR83(CCO″ and CCO′) energise. RR82 de-energises.

84. Holding circuit of R83 and RR83.

85. R85(MEX) energises in series with R54.

86. R86 energises. RR12 de-energises.

87. Holding circuit for R86, in series with one winding of R57(IS), which energises (the B wire is insulated). The feeder circuit then operates as described in connection with Fig. 190.

88. Holding circuit for guard relay R81.

89. R89(ME) energises.

90. Holding circuit for relay R89.

91. R91(MECO) energises and the called line is extended to the speech repeater. R85 and R54 de-energise.

When the feeder has been connected through to its speech repeater R86 de-energises.

92. R92(A′) energises.

93. Holding circuit for R81.

94. R94(B″) and RR94(B′) energise in the loop to the called party.

95. Holding circuit for R91(MECO).

96. Feeding coil M96, for calling line, connected.

97. Holding circuit for R81.

The circuit is now in the talking condition.

To Break Down the Connection.—When the loop is opened at the feeder, as described for Fig. 190, R92 de-energises, then R94, RR94 and R81(G). Circuits 83 and 90 are opened and all relays return to normal.

Section 78

CIRCUITS OF A SUBSCRIBERS' UNIT, OR SUB-GROUP

The subscribers' unit is made up of a plurality of subscribers' lines, which are fitted with relays, which are the equivalent of line switches or preselectors of other systems. In a sub-group of 10 subscribers' lines, each line usually has associated with it six link-connecting relays, by which connection may be made with six or 12 outgoing trunks, and a similar number of incoming trunks.

In Fig. 197 six subscribers' lines are shown, and are made to represent the different services that may be obtained through such a unit. The line A has full direct service and is furnished with a meter. B is similar but has no meter. C, D, E represent an installation of three exchange lines to a sub-station. X, Y represents a two-party line.

The subscribers' line wires are drawn vertically and intersect six links, only three of which are shown in the diagram. The links are indicated by horizontal lines, the talking circuit of the third link being numbered 5 at different points. This No. 5 circuit is carried over six (representing 10) subscribers' lines, two outgoing trunks and two incoming trunks.

The circuits are numbered to correspond with the key diagram Figs. 188, 189, and the operations involved in a connection are described in schedule form in connection therewith. In some cases the same piece of apparatus is identified by two different relay or circuit numbers. The lower numbers refer to an outgoing call and the higher ones to an incoming call. In Figs. 188, 189 the subscribers' unit is repeated at the outgoing end, and at the incoming end of the complete circuit.

As the connection assumed is over the third link the test relays LM′ and LM2 are engaged, and therefore, in open circuit, so that they cannot energise, and therefore LM3 is energised in circuit 3.

For an outgoing call R4(LC) is energised to connect the two vertical wires 5 of subscriber A to the corresponding horizontal wires, also marked 5, of the third link. Relay R3′(OTC) is energised to connect the link wires 5 to the A and B wires of the outgoing trunk.

The holding wire 8 is in parallel over all the R4 relays of the subscribers' lines, and then passes directly to relay R8′(LB) winding, the other side of which is connected in parallel to all the windings of the outgoing and incoming trunk-connecting relays R3′ and R46, the one energised then extending this circuit to the out or in holding wire H.

MW is the marking wire over which the initially energising circuit is completed on an incoming call (as, *e.g.*, circuit 42) on line X, Y.

The lines A and B operate in a similar manner.

The lines C, D and E have a common directory number by which they may be called successively, say, for day service, and have each an individual number by which any particular line may be called, as for night working, when one or other of the offices might be closed.

It will be seen that if relay F on line C is energised, the marking wire MW is switched through to the line relay of the line D, over circuit *a*. If C and D are both busy, the wire *a* will be further extended, by the wire *b*, to the line relay of the line E. If the three F relays are energised, but one energisation is due to a fault (when the associated cut-off relay CO will be de-energised), a signal will be given at a fault desk.

For individual calling, marking wires are connected at the points marked *d*.

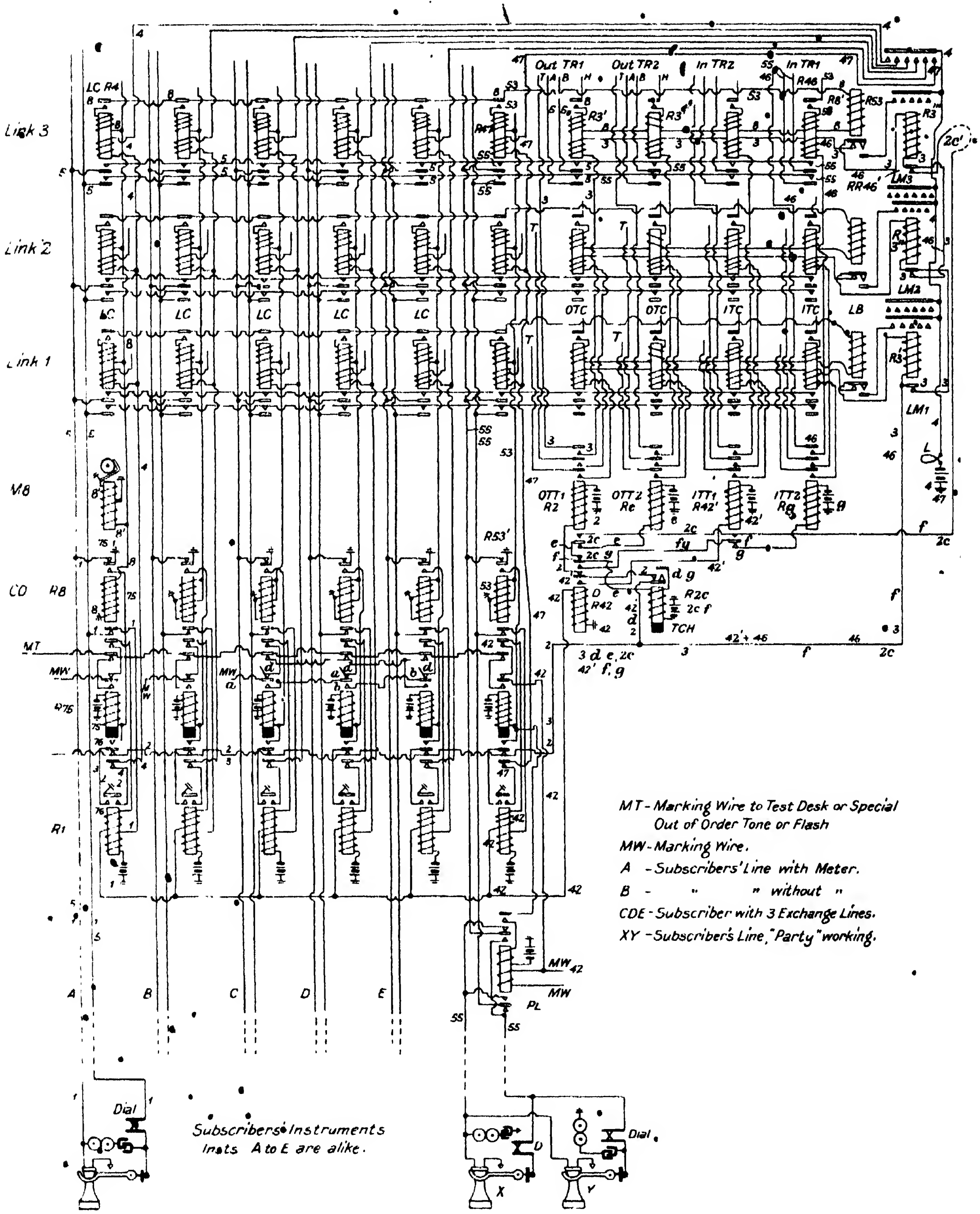


FIG. 197.—OPERATING CIRCUIT OF A SUBSCRIBERS' LINE SUB-GROUP (R. A. T. CO.).

The Party-line X, Y.—When circuit 42 is extended, as shown, the relay PL does not energise, and the connection will be extended to the telephone X. If, however, circuit 42 is extended to the lower marking wire MW, the relay PL will energise, be held in the third conductor circuit, and the connection be extended to the telephone Y.

Special Testing.—With two outgoing and two incoming trunks per link, it is necessary to test all the trunks in a vertical line over relay OTT1 or over ITT1 (Fig. 197), before the second set of trunks are tested. Relays D and TCH are introduced for this purpose. The operation is as follows :—

For an Outgoing Call.

2. When the line relay energises on a call, relay OTT1 energises, and the testing proceeds as before described.

When all the trunks over the OTT1 relay are busy –

2(*c*). Relay R2*c*(TCH) will energise, the circuit being over all the back contacts of the relays LM, and by the return path.

(*d*) Holding circuit for relay TCH. Circuit 2 is open and relay OTT1 de-energises.

(*e*) Relay R*e*(OTT2) energises, and the second set of trunks are tested as before.

For an Incoming Call.

42. R42(D) energises for a call over MW.

42′. R42′(ITT1) energises and the LM relays test as before.

If all the incoming trunks over relay ITT1 are busy –

(*f*) Relay TCH energises.

(*d*) Holding circuit for relay TCH. Circuit 42′ open and ITT1 de-energises.

(*g*) Relay Rg(ITT2) energises, and the test proceeds as before.

Section 79

A THREE-DIGIT FINAL STAGE (Figs. 198 199)

A group of, say, 60 trunks has access to a group of 1,000 subscribers' lines.

In the diagram (Fig. 198) each circuit is represented by a single line.

The incoming trunks, marked IT, are shown in four sub-groups of four lines. There may actually be four sub-groups of 15 lines or six sub-groups of 10 lines, or the like.

Extending the incoming trunks to the subscribers' unit links are three sets of short lines or links, which may be called first, second and third links, each set being divided into sub-groups.

At the point of intersection of incoming trunks to first links, a relay R51(OLC) is fitted, as indicated by X's. If there are 10 lines in each direction there will be 100 relays at that point. Between the first and second links there is only a relay R51(LLC) at each intersection of corresponding lines, so that there are only 10 connecting relays for each sub-group, shown by X's placed diagonally. Between the second and third links there is again

a square of 100 relays RR51(ILC). These third or incoming links are multiplied over a plurality of subscribers' groups R47. The third or incoming links are connected with the corresponding links of the subscriber's unit by relay R42′, which is energised when an incoming call is made.

Fig. 198 is a diagram of the circuit showing how such an arrangement is operated. The testing and holding circuits only are shown, the line or talking circuit being eliminated, so as to simplify the diagram. The actual talking circuit is shown in Fig. 191.

When a relay R41(OTM) is energised all the relays R45(OLM) of a sub-group energise, say 10, and each connects 10 wires to a sub-group of 10 links to battery.

When the relay R42′ at the subscribers' unit is energised (see Fig. 189), six of the 10 third links are extended to six links of the subscribers' unit and a relay, corresponding to RR46′, energises (depending on what links are busy, in a manner described for Fig 197). A corresponding relay RR46(ITM) is energised and completes a circuit 48 so that the common relay R48(SS) energises. This completes a circuit 49 to energise a relay R49 (in the manner described for Fig. 191) so that an R51′(LLC) relay at the point of intersection may operate.

When relay RR46(ITM) energised it connected 10 relays RR51(ILC), vertically over ITM to battery, and the relay R49(ILM), which has been energised determines which one is to energise over circuit 51. The line from RR51 is connected in parallel with 10 wires at relay R49, but only one of these is connected, through R51(OLC), to earth at R41(OTM). The holding circuit 52 is then established and the initially energising circuit disconnected. This latter circuit is only established momentarily. RR52(ITB) establishes the holding circuit 53 for the relays in the subscribers' unit.

These circuits should be read in connection with the key diagram Fig. 191, in which corresponding symbols are used.

DIRECTOR OF INDUSTRIES. LIBRARY. 13 JUL 1925 BENGAL.

AN AUTOMATIC SYSTEM

UTILISING

RELAYS FOR NON-NUMERICAL SWITCHING AND ELECTRO-MAGNETIC STEPPING MACHINES FOR NUMERICAL SWITCHING

USED BY

COVENTRY AUTOMATIC TELEPHONES, LTD., LONDON

AND

THE NORTH ELECTRIC MANUFACTURING COMPANY, U.S.A.

Section 80

SYSTEM OF THE COVENTRY AUTOMATIC TELEPHONES, LTD.

This system, that of the North Electric Manufacturing Company of the United States, sometimes called the Clement Automanual System, has been in use for some years in the

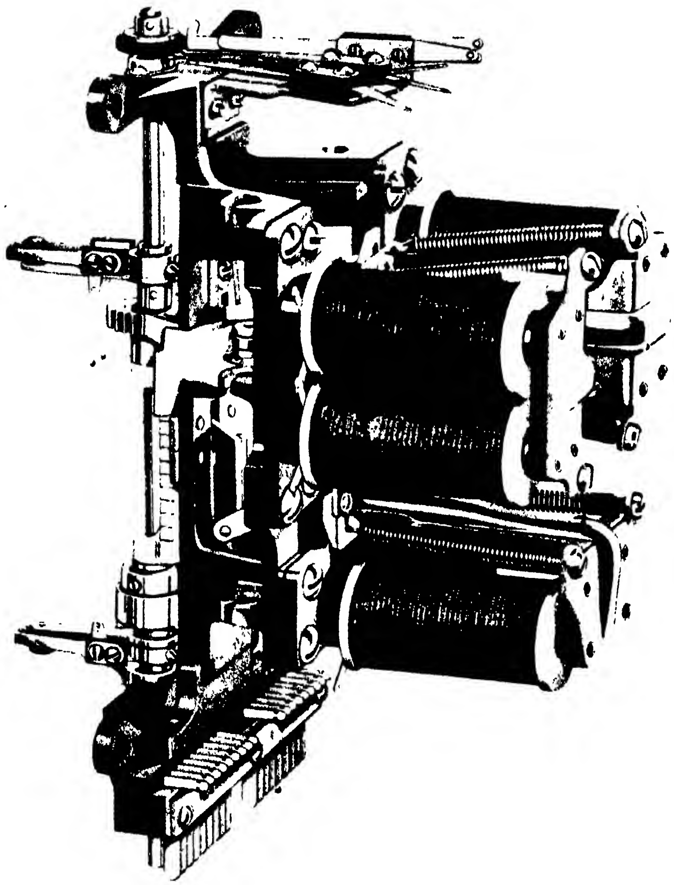


FIG. 200.—SELECTOR AND CONNECTOR (C. A. T., LTD.).

United States, principally as a semi-automatic system. It is to be used in this country as a full automatic system, and is to be installed in Dundee for the Post Office.

Complete circuits for this automatic system are not yet available, but sufficient is disclosed in the automanual circuits to show what the system is capable of doing and how it

operates. The manual features of this system are not shown here, but will be dealt with in the semi-automatic section of Vol. 2

Fundamentally, this system is similar to the Strowger system, in that it uses a two co-ordinate 100-line switch as selector and connector. This switch, however, makes the rotary movement before the vertical one. The principal advantage of this is that the bank terminals (Fig. 201) are on edge and, therefore, present less surface on which dust can accumulate. A perspective view of this switch is shown in Fig. 200. The switch takes 10 steps in a rotary direction and 11 in a vertical direction, giving an actual capacity of 110 lines. In the connector, the rotary motion is for the tens digit and the vertical for the units.

Among other advantages claimed for this design are :—

The vertical rotary and release magnets are alike, interchangeable and easily removable. The armatures of the magnets move on adjustable knife-edge bearings. Coiled piano-wire

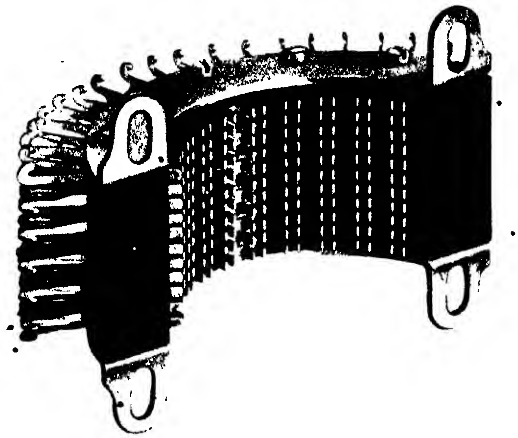


FIG. 201.—SELECTOR BANK (C. A. T., LTD.).

springs return the armatures to their normal position. (As the pitch of the screw-thread is slightly different from the normal pitch of the spring convolutions, there results a binding of the spring on the screw which effectively prevents the screw from working out). The magnet coils are each bridged by a small flat condenser to prevent sparking, and these are attached directly to the coils by clips.

A selector or connector with its associated apparatus is mounted on a ribbed steel plate (shown in Fig. 202). The switch mechanism may be removed by undoing four machine screws. The connections are carried through contact springs to facilitate this. At the bottom of each switch plate there is a row of miniature knife-blade switches by means of which the various circuits may be opened or closed for testing purposes.

An auxiliary switch (Fig. 203) called a *distributing switch*, is used for primary control, guard circuits, party-line frequency selection, key-set registers and sequence determination on operators' senders.

This is a 20-point switch having rotary motion only, there being no release or return. The magnet is interchangeable with that on the two-motion switches.

Non-numerical or Preselector Switches.—These are of the line-finder type, but do not hunt. They consist entirely of relays. In Fig. 204 is shown an outline of such a switch or combination, to show the fundamental idea of operation. It may not correspond in detail to that described in the later diagrams. The switch consists of 20 relays, 10 associated with a tens digit and 10 associated with a units digit. Ten relays close 31 contacts, for 10 × 3 lines, and a holding circuit, and the other 10 relays close four contacts. The 10 multi-contact relays may be said to have 10 levels of contacts, and from the diagram it will be seen that each level is connected to contacts of different relays on the second set of relays, which are all wired in multiple to a trunk line. When a four-contact relay is energised the trunk line is extended to the wires of a level, and when a multi-contact relay is energised that particular line at the point of intersection is

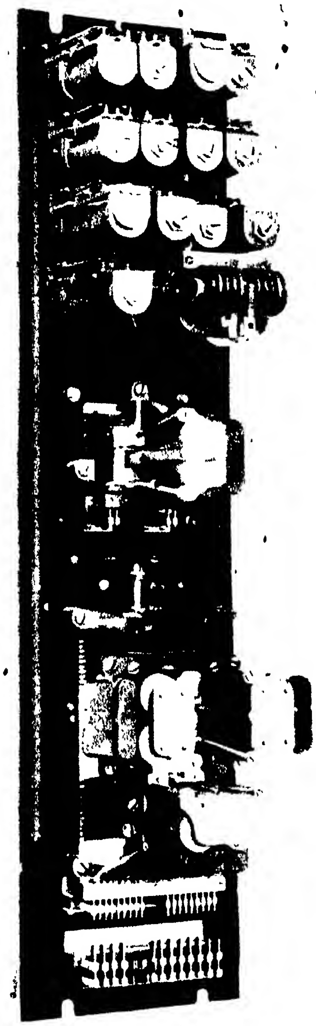


FIG. 202.—A CONNECTOR UNIT PLATE (C. A. T., LTD.).

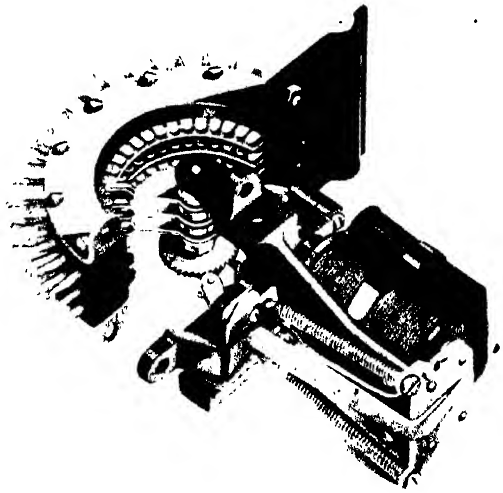


FIG. 203.—DISTRIBUTING SWITCH (C. A. T., LTD.).

connected to the trunk. Other nine lines are connected to insulated wires by the multi-contact relay. Two relays must, therefore, be energised for a connection, and each line relay has two contacts for this purpose, wired to the particular relays of the switch which combine to connect that wire to the trunk. One talking circuit only can be completed at

a time over such a switch, and 10, or other required number for the traffic, are provided, and means to extend the code wires from switch to switch as they become busy.

It will thus be seen that there is no hunting or finding the calling line, instead, that each line has a predetermined code by which the switch is operated to connect with a calling line.

Fig. 205 is a perspective view of the multi-contact relay. Each contact consists of a phosphor-bronze blade adapted, when the armature is attracted, to slide up between two german-silver springs. This form of relay has proved most successful in practice.

Fig. 206 shows the smaller or leaf-spring relay. The air-gap is adjustable by moving the core in the frame, where it is held by a heavy lock nut. The armature extension, which causes the movement of the springs, points in the same direction as the springs, so that a small air-gap is sufficient.

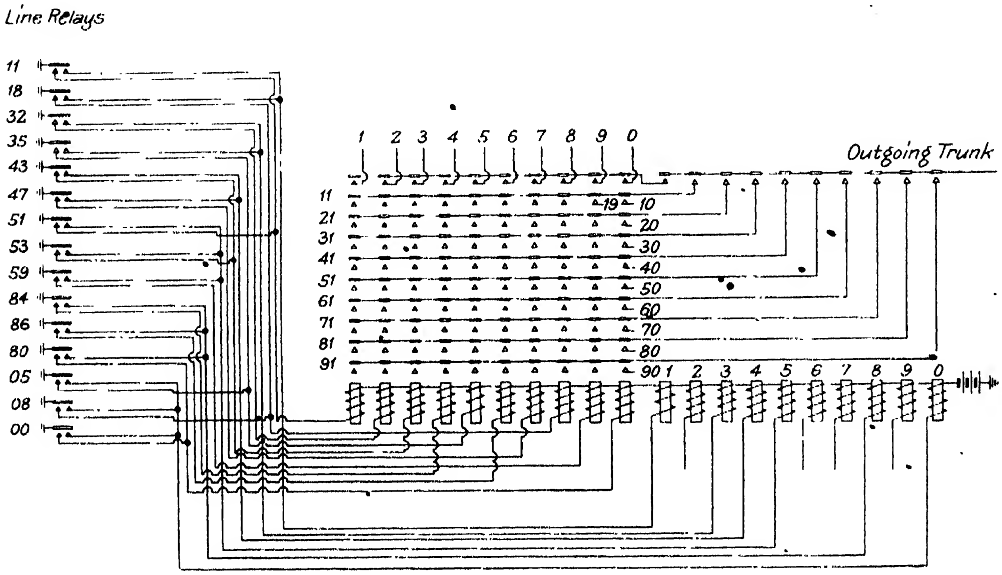


FIG. 204.—OUTLINE OF 100-LINE RELAY PRESELECTOR (C. A. T., LTD.).

The apparatus is mounted on steel frames in bays or panels. Fig. 207 shows a panel for 200 line and cut-off relays, two sets of relay preselectors and two sets of first selectors.

The line and cut-off relays are assembled in vertical rows on the lower right hand portion of the frame. To the right of these are the relay line-finders or preselectors. These relay switches are assembled in vertical rows. The first group switches with associated relays are mounted on the upper part of the frame. The first group switch is associated directly with the first line-finder and is not accessible to other line-finders, assuming there are no second line-finders.

At the top is fitted an apparatus plate supplying fuse protection and alarms for the various circuits.

The power leads to the various circuits originate at the fuse plate, and are carried in treated kiln-dried poplar conduits. The leads consist of No. 10 bare tinned copper wire, with

terminal clips properly spaced for the circuit taps. Each branch circuit is supplied with an individual cut-out and fuse-relay for alarms. Both visible and audible alarms are provided.

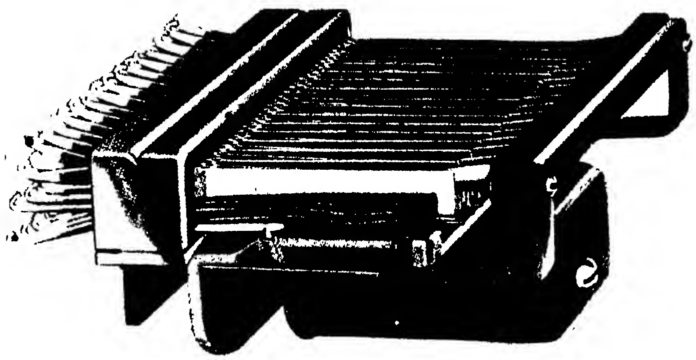


Fig. 205.—Multi-Contact Relay (C. A. T., Ltd.)

Second Group Selector Bays.—Each has a capacity for 82 second selectors, two plates being used for fuse protection and interrupters.

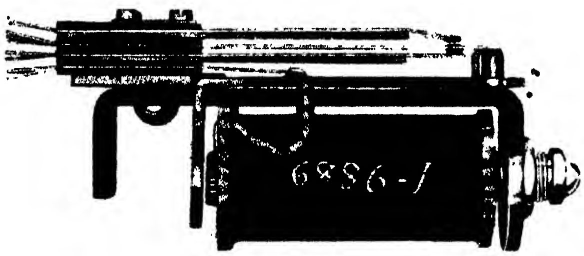


Fig. 206.—Leaf-Spring Relay (C. A. T., Ltd.).

Connector Bays.—The unit has a capacity of 44 connectors. These connectors are either for single station lines, or, for 4, 8 or 10 party lines, as they operate on the terminal per line basis.

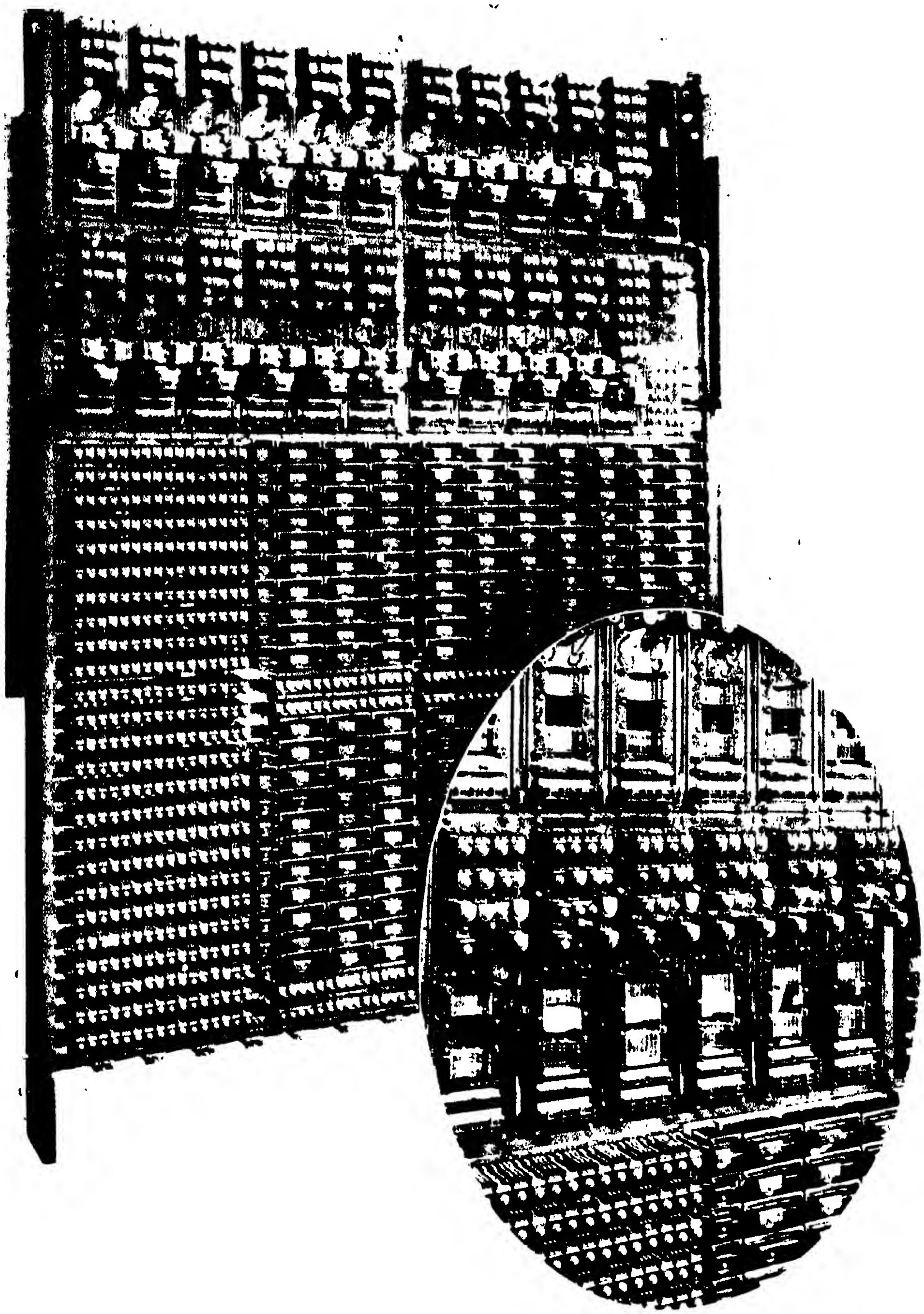


Fig. 207.—200-line Bay of Primary Equipment (C. A. T., Ltd.). Detail of Upper Part of Same.

Section 81

OPERATION OF THE AUTO-MANUAL SYSTEM

The operator-controlled machine-switching system employs trunking means between numerical groups of subscribers' lines, in a manner similar to the subscribers' controlled or dial type of machine switching. The essential variations in the general trunking scheme are the provisions made whereby an operator assumes control of the functions of the switching mechanisms instead of the subscriber. The extent of the provisions are governed by traffic requirements, and the geographical relations between the switching mechanisms and the operators' positions.

Nominally, the units of trunking are: line-finder, first selector, connector, secondary and tertiary trunks and operators' keyset. Assuming an originated call in a 10,000 line system the apparatus will operate as follows: —

A line-finder trunk connects directly to the calling line, without a hunting acting, but by fixed preferences due to the numerical position of the line in its sub-group. A secondary trunk will then connect directly to the line-finder, with the same indifferences due to its numerical position. The tertiary trunk will now connect the secondary trunk to the keyset before an idle operator. A preference is usually inserted at this point to predetermine which idle operator, also which keyset on her position, shall receive the call. The time taken in selecting an idle keyset is about half a second. The arrival of the call is indicated by a calling lamp, whereupon the operator depresses her answering key and receives the number of the called line, depressing the digits on her keyboard as they are given. Upon depressing the start button current of proper polarity passes over the tertiary and secondary trunks to a first selector associated with the line-finder in use, causing the first selector to rotate its wipers horizontally. The keyset mechanism registers the number of steps taken until they correspond to the digit depressed in the thousands row on the operator's keyboard. The driving current is now removed from the horizontal to the vertical driving magnet, and the first selector switch lifts its wipers vertically, to contacts leading to the second selectors associated with the thousands sub-group in which the called line is to be found.

Busy second selectors present positive potential to the test wiper of the first selector, causing it to pass on. Upon reaching an idle contact, as indicated by no potential, the first selector is stopped, extending the calling circuit to the idle second selector.

Driving current is now placed to the horizontal magnet of the second selector, causing it to rotate in accordance with the key depressed in the hundreds row of the keyset. The second selector then tests vertically in a manner similar to the first. The second selector will come to rest on contacts leading to an idle connector, associated with the hundreds sub-group containing the called line.

Driving current is then placed to the connector switch, first rotating its wipers in accordance with the tens key depressed, and then lifting its wipers vertically in accordance with the units key.

Should the called line serve more than one subscriber, the ringing frequency switch is then rotated to the proper kind of ringing current, and ringing begins immediately by means of a ringing interrupter associated with each connector.

As soon as the key set has registered the last digit the secondary and tertiary trunks

release, removing the operator's control from the established connection, and permitting the secondary and tertiary trunks and the keyset to be used by another line-finder. The time consumed per call by the switch operating mechanism varies from 6 to 10 seconds.

The calling subscriber controls the disconnect for the line-finder, and first and second group switches. The called subscriber controls the disconnect of the connector switch. Either party may free himself at any time from the built-up connection, and immediately recall an operator by operating the switch hook.

The system is operated on a 40-volt battery.

Section 82

CIRCUITS RELATING TO AN AUTOMATIC SYSTEM

Figs. 208 to 211 inclusive show the circuits for a four-digit system. Impulsing is from an operator's position, but in full automatic practice would be from the subscriber by dial in the usual way; but the necessary modifications are not shown. The circuits, however, show the operation of a preselector, first and second group selector and a connector, and, therefore, give a good idea of this system in automatic working.

The circuits and their operation are as follows :—

1. Receiver of, say, line 11 lifted, and R′ energises (Fig. 208). The line relay is normally adjusted to operate through a resistance of 1,000 ohms, but not to operate through 3,000. The line relay operates three contacts, two to operate the preselector, and the third to operate a guard circuit, common to this particular sub-group, which provide a time period for a one motion switch, the wipers and bank contacts of which are denoted as *bottom*, *middle* and *top*. This switch serves the following purposes :—

(*a*) Should a calling line fail to be seized by a preselector within a predetermined period, the switch will operate and shift the starting wire to the line finders, thus permitting the next trunk to hunt for the calling line. An alarm is sounded when this time limit is exceeded, or when the group is overloaded.

(*b*) It shifts the starting point to line-finders during normal pauses between calls, thus equalising the load and wear on line-finder trunks.

(*c*) It shifts the critical point in the line-finder control circuit, and serves to equalise the natural preference in line-finder selection, due to the numerical position of the calling line.

2. Guard circuit R2 energises.

3. Locking circuit of R2.

4. R4 energises.

5. R5 energises and opens the normally closed circuit 0. If R0 is de-energised for a sufficiently long period it closes an alarm circuit to indicate that the calling line has not been seized within the prescribed time. In normal operating R0 is prevented from releasing its armature because the preselector seizes the calling line at about the time R5 energises. These relays are slow to release, and R4 remains energised for a short period after R2 has de-energised.

6. Motor magnet M6 energises.

7. R7 energises.

8. R8 energises and prevents the continued energisation of the control switch magnet over circuit 9.

9. Circuit for control switch magnet, referred to above.

M6 de-energises, circuit 7 opens, and R7 and R8 de-energise.

M6 de-energising moves the wipers one step. Due to this displacement of the *bottom* and *middle* wipers a line belonging to the first group of 10 lines, to which the present calling line is assumed to belong, cannot initiate a call unless no call is being initiated in the other sub-groups of lines. The lines belonging to the second sub-group will have first choice of initiating calls. This is so because, as will be seen later, the tens relay R10 cannot complete the circuit for R13 unless all the tens group relays are idle, whereas the second tens relay may complete the energising circuit of the next R13 relay, serving the second sub-group of lines irrespective of the condition of the other group relays. Due to the displacement of the *middle* wiper, the primary selector being considered cannot be selected unless no call is being initiated in the group. Another preselector controlled by relay 2U will be selected, with preference upon the initiation of the next call.

10. Tens control relay R10 energises. There are 10 such relays. Their function is to prevent interference between simultaneous or nearly simultaneous calling lines.

11. R11 energises. The wire 10 to the back contact is common to all the line relays belonging to this particular tens group: in this instance, lines 11, 12, 13 19 and 10. The opening of circuit 10, and the like, prevents other tens control relays from receiving energising current from their respective groups of line relays.

12. Locking circuit of R10.

Earth is connected through the wiper and *bottom* bank contacts of the guard switch. This is connected through a series loop so that if more than one tens control relay be energised, that nearest to the wiper contacts will be energised only.

13. R13 energises.

14. Circuit 14 extended to the units control relay R14 (other line relays of this same tens group that may be energised are also extended). There are ten units control relays.

15. R15 energises and prevents other control relays from becoming energised and places ground to the wiper marked *top*, which is in contact with a *start* wire.

16. R16 energises (Fig. 209). This is a control relay for a particular line-finder trunk. It carries 10 energising circuits from relay R13 and 10 from R14. These wires are multipled to similar contacts on R16 relays of all line-finder trunks serving this particular 100 lines, but the *start* wire only starts the line-finder selection relays belonging to the particular line-finder trunk determined by the position in which the one-way control switch happens to stand.

There are 10 R17 relays associated with each line-finder trunk. Each carries three wires from 10 subscribers. These wires are multipled to corresponding relays of other switches. There are 10 relays R18. It will be seen that the operation of one R17 and one R18 will connect a trunk to one particular line of a sub-group.

17. R17 energises.

18. R18 energises.

19. The calling line is extended to an outgoing trunk. R19 energises.

20. Cut-off relay R20 and R20′ energise in series.

21. Holding circuit of R17.
22. Holding circuit of R18.

R′ de-energises and the control circuit is released.

R16 de-energises and shifts the *start* wire from the *top* bank to the next available line-finder. The sluggish relay R25 prevents the extension of the start wire before the completion of the line-finder selection.

23. R23 energises.
24. Holding circuit of R23.
25. R25 energised after R16.
26. Circuit from VON contact to operators' desk circuits.

The operation of secondary and tertiary switches to connect up the operators' keyboards will not be dealt with here. The reader is referred to Vol. 2 for these.

When the number has been received, set up on the keys, and the start key depressed to call the party wanted, then :—

30. R30 energises to open the line circuit to the caller, and associates the energising circuit of the first group switch with the upper side of the secondary talking circuit.
31. R31 energises.
32. R32 energises.
33. Rotary magnet RM33 energises.
34. R34 energises. Circuit 32 opened and R32 de-energises, and in turn RM33 and R34. The first group switch has now rotated its wipers one step. Circuit 31 is again closed.

The first group switch and the register at the desk now step in unison. While the sender register is restoring to normal the following is taking place at the first group switch :—

At the first energisation of R31, R32 energised and retains its armature attracted for a short time after the de-energisation of R31. Upon the cessation of the rotary driving of the first group switch, the circuit for R31 cannot be reclosed when the relay R34 becomes de-energised and R32 de energises.

35. R35 energises.
36. R36 energises to open the circuit to the caller.
37. Vertical magnet VM37 energises. R34 energises, and in turn opens the circuit to the vertical magnet, thus causing the first group switch to lift its wipers one step. The wipers *d* and *c* are now in contact with the test wires leading to the first second-group switch of the, say, fourth thousand available to this particular first group switch. Should this second group switch be busy, the test contact will present positive battery to wiper *c* and maintain the locking circuit 38 of relay R35, thus continuing earth over circuit 37 to the vertical magnet. Upon reaching an unearthed second group switch, R35 de-energises, and the first group switch wipers come to rest and extend the talking circuit to the idle second group switch. R36, which opened the line circuit while the *a* and *b* wipers were passing over busy lines, now de-energises. When the wipers were lifted vertically the contacts VON1 are opened.

39′. R39′ energises and is then held over circuit 39 and R39 energises.
40. Earth is connected to the test terminals of the second group switch to make it test busy to other switches.

Operation of Second Group Switch and the Sending of Hundreds Impulses (*Fig. 210*).

41. R41 energises over the *a* wiper of the first group switch.

42. R42 energises.

43. Rotary magnet RM43 energises.

44. R44 energises. Circuit 41 is opened and the second group switch moves its wipers one step in a rotary direction.

The sluggish relay R42 does not de-energise when R41 pulsates during the rotary motion. When the driving current is removed by the sender, R42 de-energises.

45. R45 energises.

46. R46 energised when the switch moved out of its normal position.

47. Holding circuit for R46 over circuit 40. R45 now energises.

48. Vertical magnet VM48 energises. R44 energises over circuit 44.

Circuit 48 is opened, VM48 de-energises, lifts the wipers one step vertically, and tests for an idle connector, in the manner as described for the first group switch.

49. R44 energises.

50. R45 is maintained energised over the test wiper and terminals of busy trunks. RON contacts are closed.

51. R51 energises during the stepping operations to open the line. Upon reaching an idle connector R45 de-energises, then R51 and wipers *a′* and *b′* extend the talking circuit to the connector.

52. Earth to wiper *d* and terminals to busy the circuit.

Connector Operation and Sending of Tens and Units Impulses (Fig. 211).—

55. The sender functions as before and R55 energises.

56. Rotary magnet RM56 energises.

57. R57 energises and opens the sender circuit. This is repeated.

58. R58 energises after R55.

59. R59 energised after R58.

Circuit 55 is opened and R55 de-energises for a period long enough to allow R58 to de-energise.

60. Locking circuit for R59, so that it does not de-energise.

61. R61 energises.

62. Locking circuit for R61.

Circuit 55 is again closed and R55 energises.

63. Vertical magnet VM63 lifts the wipers vertically, the interruption of the magnet circuit being controlled by the relay R57 over contact 57′, as before. When the selection is completed, R55 de-energises and prevents the further movement of the connector. During the pulsating of R55, R61 is locked over R58. Upon the permanent de-energisation of R55, R58 de-energises, then R61.

Selection of Party Line Ringing Current.—R55 is energised, then R58.

64. R64 energises.

65. Contacts VON1 being closed, the motor magnet of the ringing selector, RgM65, energises and, by the agency of R57, interrupts its own circuit. The *ringing selector* is a one-way switch, having three wipers and three sets of contacts, marked *bottom*, *middle* and *top*. The *bottom* contacts select the kind of ringing current, the *middle* wipers connect earth to the proper side of the line whilst ringing, and the *top* wipers are used to restore the switch to normal. The ringing selector switch is controlled from the keyboard. After ringing, R55 de-energises, then R58 and R64.

Testing of the Called Line.—If the called line is idle, then full battery potential is connected through its cut-off relay to the test terminals.

66. R66 is energised when the *top* wiper of the ringing selector is moved out of its normal position.

67. The test contact is momentarily to the winding of the test relay R67.

A busy line presents a positive potential to energise the high resistance relay R67.

68. R68 energises.

69. R68 locking circuit. Busy signal given to caller who then replaces his receiver.

When the called line is idle, the test wipers receive negative battery and R67 does not energise.

70. R64 presently de-energises and the marginal relay R70 energises.

71. Rg71 energises in series with R71′, and through the agency of R72 cause the successive opening and closing of the circuit, whereby the relay Rg71 is intermittently operated. This relay rotates a shaft carrying a set of cams, shown as Nos. 1 to 8 directly above the motor coil. Its functions are, first, to place current to the called line for a certain period, and in so doing remove the battery potentials from the line circuit; secondly, to discharge the line periodically, and, thirdly, to place the battery potentials to the line during the silent period of the called party's bell. During one-half of each revolution of the shaft the cams 3 and 4 maintain their contacts closed, completing a circuit from earth, through a 20-cycle or a 60-cycle generator (depending upon the displacement of the party line switch), the *bottom* wiper, the contact of, say, cam 3, the lower armature and back contact of relay R87, wiper 3, the associated terminal and the bell of the called station to earth. Depending on the position of the *bottom* and *middle* wipers, one of the ringing current generators is connected to the tip or ring side of the line, whereby one of the four-party line stations may be signalled, to the exclusion of the others.

Cam 6 controls the sending of a ring-back tone to the caller, to inform him that the called party's bell is being rung. Cams 3 and 2 open and close the talking circuit during the ringing and silent periods respectively, and cam 5 discharges the line during each revolution of the shaft. Cam 8 ensures the return to normal of the shaft. The above-mentioned processes continue until the called party lifts his receiver, or the caller replaces his.

73. Assuming that the called party answers, R73 energises. R59, R61, R71′ and R72 release and also open the circuit to the ringing interrupter, so that it comes to rest in its normal position.

When the operator's controlling equipment is disconnected R30 and then R39 de-energise. The talking circuit is then complete.

When disconnection is desired the subscribers replace the receivers.

Release of the Equipment Controlled by the Caller.—When the calling line is opened R19 de-energises, then R23.

80. R80 energises.

81. Locking circuit of R80.

82. R82 energises.

83. Release magnet energises and restores switch to normal.

When the switch is restored to normal, and before R80 has time to de-energise, RON contacts open the locking circuits 21′ and 22′ of the preselector relays R17 and R18, to release the calling line. R20 and R20′ de-energise, also R80 and R36.

At the second group switch R46 de-energises.

84. R51 energises.

85. Release magnet energises and restores the switch to normal.

Contacts RON are opened and R51 de-energises and circuit 85 opened.

Release of Equipment Controlled by Called Party.—The connector does not release until the called receiver is replaced. When the line is open R73 de-energises.

86. The ringing selector, with the co-operation of R57, causes the rotation of the switch RgM65 until the top wiper reaches its normal position, when R66 de-energises and opens the circuit 86.

Circuit 67 + 70 is opened and the COR and R70 de-energise, and the called line is free.

87. R87 energises.

88 + 86. Release magnet energises. The connector is restored to normal when it reaches its zero position, contacts RON are then opened, R87 de-energises and opens the release circuit.

Release when the Called Party is busy is similar to the above, but the connector automatically returns to normal.

R67 is operated on a busy line, as described. R68 energises and is locked over circuit 69. R73 is not energised, circuit 87 is closed and R87 energises, and completes the release circuit when R66 de-energises, as described. R68 is unlocked when the wipers of the second selector leave the connector test terminals under control of the caller.

DIRECTOR OF INDUSTRIES. LIBRARY. 13-JUL.1925 BENGAL

Section 83

INTERIM BRITISH STANDARD TERMS AND DEFINITIONS FOR USE IN CONNECTION WITH AUTOMATIC TELEPHONE SYSTEMS *

This interim list of terms and definitions has been prepared in conjunction with the British Post Office, the Telephone Manufacturers' Association, and the Relay Automatic Telephone Co., Ltd.

It includes, with a few exceptions, only those terms on which agreement has been reached after correspondence with the American Engineering Standards Committee.

The Panel is continuing its work and a more complete list will be available at a later date. Every effort is being made to arrive at agreement with America in regard to these terms before inclusion in the British List.

Terms and Definitions.—1. A *Manual Telephone System* is one in which the calling party gives his order to an operator who completes the call directly by hand either with or without the assistance of other operators.

2. A *Full Automatic* (or *Full Mechanical*) *Telephone System* is one in which the calling party is enabled to complete a call without the aid of an operator by switches remotely controlled.

3. A *Semi-Automatic* (or *Semi-Mechanical*) *Telephone System* is one in which the calling party gives his order to an operator who completes the call by switches remotely controlled.

4. An *Exchange* (*U.S.A. Central Office*) is a switching centre for interconnecting the lines which terminate therein.

5. A *Private Branch Exchange* (*Abbreviation P.B.X.*) is a telephone system, installed on the premises of a subscriber, including a switchboard and extension sets, and connected to a main exchange, affording intercommunication between the extension sets and also between these sets and the main exchange.

6. A *Private Automatic Branch Exchange* (*Abbreviation P.A.B.X.*) is a private branch exchange worked wholly or in part automatically.

7. A *Private Exchange* is one which serves a business or other organisation and is not connected to a public exchange.

8. A *Private Automatic Exchange* (*Abbreviation P.A.X.*) is one which serves a business or other organisation and is not connected to a public exchange.

9. *Equipment* is the automatic switching plant and its accessories, including the switchboards used for junction and other manually operated traffic.

10. An *Operating Room* is a room of an exchange in which the manual part of semi-automatic operations is performed. This term also applies to the room housing the switchboard used for junction and other manually operated traffic at a full automatic exchange.

11. An *Auto Room* is a room of an exchange in which the automatic plant is located.

12. A *Manual Switchboard* is the part of the equipment provided to enable the manual work of the operating room to be performed.

13. A *Multi-Exchange System* (*U.S.A. Multi-Office System*) is a network of local exchanges.

* This list is reproduced from Interim British Standard Terms and Definitions for use in connection with Automatic Telephone Systems—No. 136—1920—by permission of the British Engineering Standards Association, 28, Victoria Street, S.W.1.

14. A *Subscriber's Set* (*U.S.A. Sub-Set*) is an assembly of apparatus for originating and receiving telephone calls in conjunction with an exchange.

15. A *Subscriber's Station* (*U.S.A. Sub-Station*) is an installed subscriber's set connected to an exchange (Public or Private Branch) for the purpose of originating and receiving telephone calls.

16. A *Public Call Office* (*U.S.A. Pay Station*) is a subscriber's station available for the use of the public on the payment of a fee. The fee may be either deposited in a coin box or paid to an attendant.

17. A *Subscriber's Line* is the wire connection between a subscriber's station and the exchange.

18. A *Direct Line* (*U.S.A. Individual Line*) is a subscriber's line which connects one subscriber's station to an exchange. It may have one or more extension sets.

19. A *Party Line* is a subscriber's line which connects two or more subscribers' stations to an exchange.

20. A *Reverting Call* is one between two stations on the same party line.

21. A *Calling Party* is one who originates a telephone call.

22. A *Called Party* is one who is required by the calling party.

23. *Busy* is the condition of a line or apparatus when it is in use.

24. A *Calling Device* is an apparatus by means of which automatic switches are remotely controlled for the purpose of establishing a connection.

25. A *Dial* is a calling device by means of which the calling party controls the switching mechanism.

26. *Dialling* (from the verb " to dial ") is the act of manipulating a dial.

27. A *Key Set Call Sender* is a calling device by means of which an operator manipulating keys controls the switching mechanism.

28. A *Trunk* is the wire connection between switching devices in the same automatic exchange. The connection between two exchanges is termed a " junction."

29. *Trunking* is an adjectival derivative from the term "trunk," *e.g.*, "trunking scheme."

30. A *Selector* is an automatic switching machine.

31. A *Wiper* is that portion of the moving member of a selector which engages with a bank contact.

32. A *Bank* is an assembly of fixed contacts with which the moving member of a selector engages. Banks are usually multipled.

33. *Impulse Action* is the operation of finding, by means of electrical impulses, the called line or group of lines.

34. *Hunting Action* is the operation of a selector in moving its wiper to its position of contact with an idle line in a chosen group of trunks or lines. Hunting action is automatic.

35. *Finding Action* is the operation of a selector in moving its wiper to its position of contact with a calling line connected to its bank. Finding action is automatic.

36. A *Pre-Selector* is a selector which connects the calling subscriber's line and an outgoing trunk.

37. A *Group Selector* is a selector which chooses a group of trunks by impulse action and subsequently chooses an idle trunk in the group by hunting action.

38. A *Final Selector* is a selector to the bank of which are connected subscribers' lines. A final selector moves the wiper from its position of rest to its position of contact by impulse action.

39. A *Private Branch Exchange Final Selector* (*Abbreviation P.B.X. Final Selector*) is a selector which in addition to the standard operations of a final selector, finds an idle Private Branch Exchange junction by hunting action.

40. A *Line Finder* is a preselector electrically connected so as to operate by finding action.

41. *Level.* The contacts of the bank of a group selector, which taken collectively are found by a definite impulse action. The contacts in a level are generally (but not necessarily) arranged horizontally. Contacts similarly arranged in a final selector are also collectively known as "level."

42. A *Sequence Switch* is a mechanical device for making a number of electrical contacts in a definite order. A sequence switch is frequently employed to effect the change over conditions of selectors.

43. A *Master Switch* is a device which controls electrically or mechanically or by both means a group of pre-selectors.

44. The *Positive Side or Positive Wire* (+ *Wire*) *and Negative Side or Negative Wire* (— *Wire*) are the wires of a telephone line within the exchange premises associated with the automatic equipment. The + and — wires are respectively connected with the positive and negative poles of the exchange battery when the line is idle.

45. *T side or T Wire* (*Tip side or Tip Wire*) *and R side or R Wire* (*Ring Side or Ring Wire*) are the internal wires of a telephone line associated with a manual switchboard. "T" and "R" wires are connected respectively to the Tip and Ring contacts of a jack or plug or to corresponding points.

46. *A Wire and B Wire* are the wires of a telephone line external to the exchange premises.

47. *Telephone Traffic.* By telephone traffic is meant the number of telephone calls considered in bulk.

48. *Telephone Traffic Unit* is the unit adopted for the measurement of the traffic carrying capacity of telephone plant. It is defined by the relation:

A (Traffic Units) = C (Calls in a specified period) × T (average duration of a call expressed as a fraction of the specified period).

NOTE—(*a*) The "busy hour" is the "specified period" for C, unless otherwise stated.

(*b*) In practical calculations A bears the three following meanings, each of which has its special field of usefulness, viz.:—

(i.) A = total circuit time occupied in carrying C calls of an average duration T.

(ii.) A = Average number of calls originated during the specified period in an interval of duration T.

(iii.) A = Average number of calls in progress simultaneously during the specified period.

THE WHITEFRIARS PRESS, LTD., LONDON AND TONBRIDGE.

Western Electric

Automatic

Telephone Systems

Manufactured by the Western Electric Co., pioneers of the Telephone industry, are in efficient operation the world over.

These systems have been produced after many years of development work by our engineers, and represent the most notable contribution yet made to the solving of the evolution of the telephone switching problem since the introduction of the Western Electric Central Battery system in 1896.

The Company is prepared to study any given telephone area or any particular exchange and to assist the prospective customer in choosing that form of system most suited to his particular conditions.

Moreover, the Company places at his disposal competent automatic telephone engineers and experts who will assist him in determining the most economical, as well as the most efficient, system for the improvement of his telephone service.

MAINTENANCE REDUCED TO A MINIMUM.

Western Electric Company, Limited,

Works: N. WOOLWICH, E. 16.

AND AT BELFAST, BIRMINGHAM, CARDIFF, GLASGOW, LEEDS, MANCHESTER, NEWCASTLE, SYDNEY, JOHANNESBURG, BUENOS AYRES.

BOOKS *for* Telephone and Telegraph Engineers and Students.

AUTOMATIC TELEPHONE SYSTEMS. By William Aitkin, M.I.E.E., A.M.I.Am.E.

Vol. II. of this book is in preparation, and we shall be glad to announce its publication to any one interested as soon as the book is ready.

THE THEORY OF THE SUBMARINE TELEGRAPH AND TELEPHONE CABLE. By H. W. Malcolm, M.A., Ph.D., D.Sc.

CONTENTS.—Mathematical Recapitulation—The Fundamental Cable Constants—Transient and Periodic Phenomena. *Purely Periodic Phenomena—The Telephone Cable:* The Telegraphic Equation and its Periodic Solution—The Methods of Loading Cables—Discontinuities and Reflexions—Alternating Current Measurements. *Purely Transient Phenomena—The Telegraph Cable:* The Telegraphic Equation and its Transient Solution—The Part Played by the Signalling Apparatus—Sending Phenomena and the Influence of Leaks. *The Methods of Telegraphic Transmission:* Signalling by Inverse Currents—Sine Wave Transmission. *The Future Progress of Cable Telegraphy:* Distortion and how it is Produced—Present-day Methods of Overcoming Distortion—The Duplexed Cable—The Loaded Telegraph Cable. *Appendix:* Useful Data—Useful Formulæ—Properties of Circular and Hyperbolic Functions—Types of Core of somewhat frequent Occurrence—Effective Resistance, Inductance and Impedance of Standard Apparatus—Constants of some Typical Telephone Conductors—Telephone Transmission Formulæ—Arrival Current, Cable without Apparatus—Arrival Current.

566 pages. Size $5\frac{1}{2}'' \times 8\frac{1}{2}''$. Price 23/- post free.

STUDENT'S GUIDE TO SUBMARINE CABLE TESTING. By H. K. C. Fisher and J. C. H. Darby.

CONTENTS.—Explanation of Terms—Simple Testing—Joint Resistance and Shunts—The Universal Shunt—The Constant of the Galvanometer—Absolute Resistance—Insulation Test by Direct Deflection—Earth Currents—Wheatstone's Bridge—To Calculate the Strength of the Currents in the Parts of a Wheatstone Bridge when Balanced—The Measurement of Copper Resistance—Capacity and its Measurement—The Battery—Measurement of its E.M.F. and Internal Resistance—The Measurement of Galvanometer Resistance—Correction of Resistance for Temperature—Preliminary Remarks—Tests for Total Breaks—The Loop Test—The Earth Overlap—Blavier Test—The Measurement of the Resistance of an Earth. *Appendix:* To find the Current in a Wheatstone Bridge—Temperature Tables—Questions—Answers—Splice List—Connections of Signalling Instruments—Connections of Wheatstone Bridge (Dial Pattern).

244 pages. Size $5\frac{1}{4}'' \times 8\frac{1}{2}''$. Price 10/3 post free.

BEGINNER'S MANUAL OF SUBMARINE CABLE TESTING AND WORKING. By G. M. Baines.

CONTENTS.—Batteries—Ohm's Law—Joint Resistance—The Wheatstone Bridge—Bridge Measurements—Insulation Test by Direct Deflexion—Inductive Capacity—Measurement of the Internal Resistance of a Battery—Measurement of the E.M.F. of a Battery—Current Strengths in Wheatstone Bridge—Tests of Broken or Faulty Cables—Description of Apparatus.

174 pages. Size $5\frac{1}{4}'' \times 8\frac{1}{2}''$. Price 10/6 post free.

COMMON BATTERY TELEPHONY SIMPLIFIED. By Walter Atkins.

This book is essentially one for the practical man and the modern student. Thus, the fourth edition, has been thoroughly revised and brought up to date, many modern methods being fully illustrated and described. The book will be published early in August and a notification sent to any one interested.

CONTENTS.—Introductory—Main Frame and Apparatus Room—Subscribers' Switchboard Arrangements—Junctions—Subscribers' Apparatus—Testing Arrangements—Miscellaneous Circuits—Appendix I—Appendix II—Appendix III—Appendix IV. Ready August.

144 pages. Size $5\frac{1}{4}'' \times 8\frac{1}{2}''$. Price 8/3 post free.

BENN BROTHERS, LIMITED,

8, BOUVERIE STREET, LONDON, E.C. 4

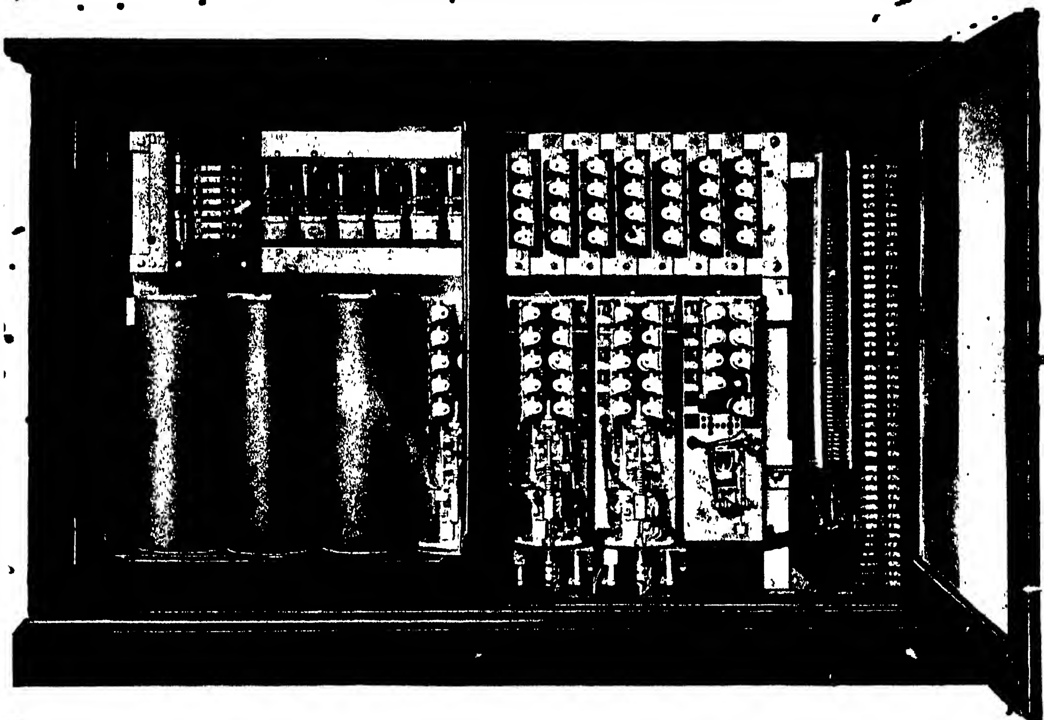
Automatic Telephone Manufacturing Company's Private Automatic Exchange

(STROWGER SYSTEM).

There are at present fifty times as many Exchanges equipped with Strowger type Automatic Apparatus as with that of all other Automatic Systems combined: Philadelphia, the largest Automatic Installation in the world, 47,000 Telephones, is on the Strowger System.

Leeds, the largest British Exchange, is equipped with Strowger Apparatus, as are also Portsmouth, Blackburn, Paisley, Newport, Accrington, Chepstow, Epsom, G.P.O. (London), etc.

Exhaustive tests extending over 30 years have proved the entire reliability of Strowger Automatic Telephone Equipment.



This 25-Line Strowger Automatic Switchboard incorporates special conference facilities, and can be adapted for Code Call, Watchman's Service, etc.

We can furnish Installations of any desired capacity, to meet all conditions of service.

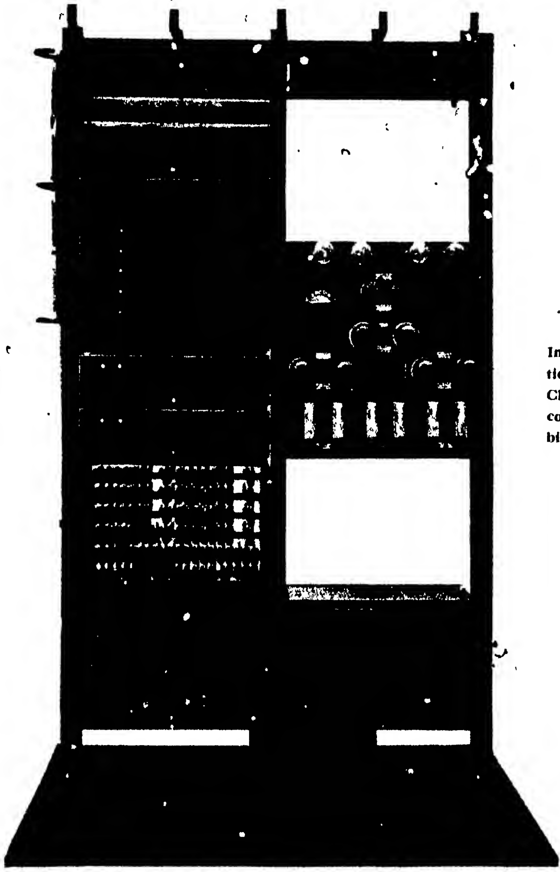
FULL DESCRIPTIVE PAMPHLET ON REQUEST.

AUTOMATIC TELEPHONE MANUFACTURING CO., LTD.

HEAD OFFICE AND WORKS:
Milton Road, Edge Lane,
LIVERPOOL.
Telephone No.: OLD SWAN 102.

LONDON OFFICE:
60, Lincoln's Inn Fields,
LONDON, W.C. 2.
Telephone No.: HOLBORN 170

This system is especially suited for Private Automatic Branch Exchanges, giving inter-communication with Public Service.



Instantaneous connection and disconnection. Clear speech. Secret conversation. Reliability. Two wires only.

50-Line Switchboard (30 lines installed), one Cover removed, showing Relays.

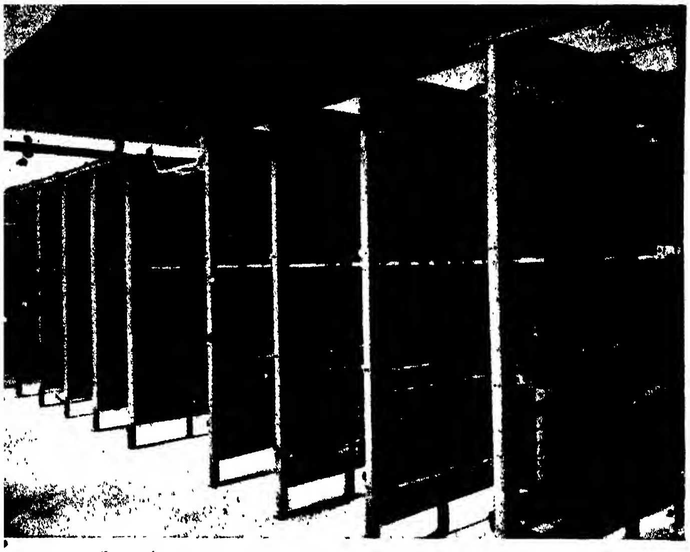
THE Authorities mentioned below obviously would not instal the Relay Automatic Telephone System without making a thorough investigation of the claims made for it, and satisfying themselves that these claims were fully justified.

The Admiralty
The British Post Office
The India Office
The Commonwealth of Australia
Anglo-Mexican Petroleum Co., Ltd
Chelsea Hospital for Women.
Aluminium Plant & Vessel Co., Ltd., London.
Educational Supply Association, London
Geo. Fox & Sons, Batley.
National Hospital for Paralysed & Epileptics
Great Northern Central Hospital.
Barclay's Bank, Ltd
Clayton, Son & Co., Leeds
Beldam Tyre Co., Brentford
Thornton Marsden & Co., Honley.
Mellish Richardson, Ltd., Leeds
North British Steel Works, Sheffield.
Davidson & Syme, Edinburgh.
Kincaid & Co., Ltd., Engineers, Greenock.
Furness Shipbuilding Co., Ltd., Haverton Hill-on-Tees.
H. Milward & Sons, Redditch.
Hull Oil Manufacturing Co., Ltd., Hull.
Bass, Ratcliff & Gretton, Ltd.
British Dyestuffs, Ltd.
Ely Paper Mills, Cardiff.
Powell Duffryn Steam Coal Co., Ltd.
The London Hospital, and others.

THE RELAY AUTOMATIC TELEPHONE CO., LTD.,

'Phone: City 281.

Marconi House, Strand, London, W.C. 2.



SEMI-AUTO EXCHANGE AT STOCKHOLM FOR 1,000 LINES.

PUBLIC EXCHANGES ARE IN COURSE OF CONSTRUCTION FOR THE BRITISH POST OFFICE, THE INDIA OFFICE, THE SOCIETA ADRIATICA TELEFONI, ROME, ETC.

From **THE ARDROSSAN DRY DOCK AND SHIPBUILDING CO., LTD.**
Shipyard, Ardrossan. **January 15th, 1921.**

Dear Sirs,

I have no hesitation in saying that an extensive interdepartmental telephone system, such as is provided by your particular system, is a necessity in modern works. With fifty lines here, we have an average of 2,500 calls per week, and it can easily be imagined from that how much time is saved, and how much more prompt attention is given to various points that arise in the course of the business of a place this size.

With regard to the mechanical side of your installation, we have no fault to find with it; it has proved itself thoroughly reliable during the time we have had it, now sixteen months, and up to all that you stated.

From **EDWARD BOUSTEAD & CO.**
149, Leadenhall Street,
London, E.C. 3. **November 25th, 1920.**

Dear Sir,—

The Relay Automatic Telephone System, which has now been installed in our London office for some twelve months, has given us entire satisfaction.

The service has been uniformly good throughout, and we have no hesitation in saying that, in our experience, the Relay Automatic Telephone System has proved to be quite the best in every way.

From **CONTRACT DEPARTMENT, ADMIRALTY.**
Avenue House,
21, Northumberland Avenue,
London, W.C. 2. **January 7th, 1921.**

Gentlemen,—

I have to inform you that the Relay Automatic Telephone System installed at the R.N. College, Greenwich, is quite satisfactory.

From **MESSRS. GEORGE FOX & SONS, LTD.**
Staincliffe, Dewsbury. **31st January, 1921.**

Gent.,—

From January 15th, 1920, when you left our Relay Automatic Telephone Installation, to January 14th, 1921, inclusive, our meter registered 10,043 calls.

As you are aware, only 19 lines are in commission, showing an average of 528 calls per line for the first year.

We are very pleased to report that we have not had one single fault during the twelve months, with the exception of outside line faults, which were due to the severe gale at the end of January, 1920.

The installation has proved entirely satisfactory in every respect.

From **THE SOUTH LONDON HOSPITAL FOR WOMEN.**
South Side,
Clapham Common, S.W. 4. **November 18th, 1920.**

Dear Sirs,—

I have pleasure in stating that the Relay Automatic Telephone System installed at this hospital has given, and is giving, entire satisfaction. We find the installation a decided time saver, and a convenience from every point of view.

THE RELAY AUTOMATIC TELEPHONE CO., LTD.,

Marconi House, Strand, London, W.C. 2.

'Phone: City 281.

For

THE LATEST NEWS

and Details of

SCIENTIFIC RESEARCH AND DEVELOPMENTS

connected with

TELEPHONES

and

TELEPHONY

READ

THE ELECTRICIAN

ESTABLISHED 1861.

ONE SHILLING WEEKLY.

Annual Subscription, post free,

£2 12s. 0d. United Kingdom;

£2 14s. 0d. Abroad.

SPECIMEN COPY FREE.

BENN BROTHERS, LIMITED,

8, BOUVERIE STREET

LONDON, E.C. 4.